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ANNUAL MEETING—UNIVERSITY OF FLORIDA
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Published in April

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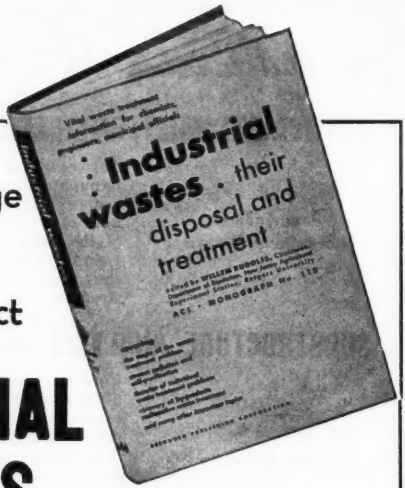

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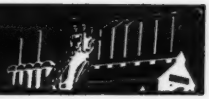
from McGRAW-HILL 

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Do You Know—

► The following are some residual items of Society activities not reported in the March or April issues of Journal.

► The Annual Meeting is just around the corner—June 22–26. By this time, you should have received the Preliminary Program and the reservation cards. Here are a few items of special interest regarding the Annual Meeting program . . . The Tuesday morning General Session Program will deal with the general theme of Engineering Education and Profession, with our own President Woolrich speaking on the subject of "Engineering Education and the Engineering Profession" and Karl McEachron, Sr., Consultant on Professional Employee Relations of the General Electric Company, speaking on "Unionism and the Engineering Profession." This subject has suddenly sprung into full-scale importance for the engineering profession as a result of expanded activities of unions . . . Perhaps you have noticed that the General Entertainment for Wednesday evening will be the current Broadway hit "Bell, Book and Candle," staged by the Florida Players. Also, President and Mrs. Miller are inviting the Membership to a reception at their home on Tuesday evening . . . For other features, please refer to the Preliminary Program. An attractive ladies program has been arranged by the Florida Local Committee.

► We have received several inquiries regarding the procedure for nomination of officers of the Society, so here is a quick resume . . . A nomination form was published in the February and March issues of the Journal. Nominations are to be sent to the ASEE Headquarters, where the information is compiled and forwarded to the Nominating Committee. The Nominating Committee consists of the members of the General Council who retire from the Council in June, together with the three immediate past presidents. The Senior Past President (this year Dean Thorndike Saville) serves as Chairman. The Nominating Committee members add their nominations, after which a tentative (non-committal) ballot is taken by mail. The final selection is made by the Nominating Committee assembled at the Annual Meeting. The nominations can also be presented on the floor of the General Session at the time of the election. If you wish to make nominations, please send them to the Headquarters Office either on the nomination form printed in the Journal or by letter.

► The Committee on Graduate Study has completed revision of the Manual of Graduate Study which is summarized in this issue of the Journal. This was a two-year project undertaken by a committee of 9 members, all of whom are actively directing Graduate Studies in engineering colleges. Our publication budget did not permit publishing the entire Manual in the Journal, but copies of the complete Manual can be obtained from the Secretary's Office at 50¢ each. Please include remittance with your order.

► The Paper Contest for Young Engineering Teachers has met with enthusiastic response from our younger members. Most Sections of the Society report at least three to five entries. Regional judging is now under way to select the semi-finals. Awards for the two prize-winning papers will be presented to the recipients at the Annual Banquet.

► At the suggestion of the Division of Relations With Industry, several Sections of the ASEE have expanded their activities and programs in order to bring into active participation a number of leading engineers and industrialists from local industry. The Sections which have undertaken this type of program have found it highly profitable, both from the stand-

point of obtaining stimulating material and also that of establishing friendly working relationships between industry and the colleges. George Lobingier, Chairman of the ASEE Relations With Industry Division, states that this Division will be glad to cooperate with any Section which wishes to develop similar activities or arrange for a sub-division of the RWI Division.

► A barrage of letters informs us with a slight tinge of chagrin, that we overlooked in our listing of publications of the Society in the March issue of the Journal, the highly commendable Bulletin of the Engineering Mechanics Division. This Bulletin is doing a superb job in bringing the latest advances in the teaching of engineering mechanics to the teaching profession. Congratulations on a good job!

► A few copies of the report of the Committee on the Improvement of Engineering Teaching are still available and can be purchased from Headquarters Office at a price of 15¢ per copy or $8.00 per hundred. Over ten thousand copies of this report have been sold, indicating its widespread popularity. Please enclose a check with your order.

► An excellent compilation of papers on the Fifth College-Industry Conference sponsored by the Relations With Industry Division is now available in mimeographed form from the Headquarters Office. This includes 11 papers dealing with recognition and encouragement of gifted students, recruiting potential talent for the engineering profession, what must the individual do toward continued learning, appreciation of the humanities by the individual, motivations in industry, and other interesting subjects. The price is 50¢ per copy. Please enclose a check with your order.

► Again may we call your attention to the fact that the Fall Meetings of the ECRC and ECAC, will be held in conjunction with the Annual Meeting of the ECPD at the Statler Hotel in New York on October 15–17. The program details for this meeting have not been fully developed, but the conferences will be open to all members of the Society.

► The Executive Board suggested that the Committees and Division of the ASEE take advantage of this Fall Meeting to hold Committee meetings for the purpose of formulating the program for the year ahead. A number of meeting rooms will be reserved at the Statler on October 13.

► The Committee on Evaluation of Engineering Education will hold a two-day meeting preceding the Annual Meeting of the Society in Florida. The work of this Committee for the past year has been financed by a grant of $3,000 from the Engineering Societies Foundation. Also, the ECPD Societies have offered to contribute funds to help finance the project. This financial assistance has been extremely helpful in making it possible for the Committee members to meet and carry on the work of the Committee.

► The new membership drive, which was aimed primarily at younger faculty members, has yielded over 700 new members. The Membership Committee deserves a hearty vote of thanks for their excellent cooperation.

► A number of Divisions of the Society are cooperating with the American Standards Assn. in preparing standards. The Drawing Division is particularly active currently in the preparation of international drafting standards.

► A study is currently under way in the English and Humanistic-Social Divisions of the Society to determine the course offerings in these fields in engineering colleges throughout the country. A report on this will be presented at the joint dinner of the two Divisions in Florida.

► Professor Sampson of the Univ. of Fla. called attention to the dinner meeting of the Young Engineering Teachers' Committee which features Rear Admiral Wm. S. Parsons, USN, on the subject "Problems of Weapon Design and Development." Incidentally, Adm. Parsons, flying over Hiroshima, attached the fuse to the first atomic bomb in history to be delivered against a military target.

"Let's Clean House"

By JOHN R. SNELL *

Head Dept. of Civil Engineering, Michigan State College

House cleaning time is at hand. It is long overdue. In fact, the point has been reached when each man must decide for himself whether he will be part of the house cleaning crew or part of the dirt. This is the conviction which has been burning deeper in me each week in the year since I closed my consulting engineering office in Metropolitan Boston and accepted my present position at Michigan State College.

This conviction was born out of my 19 years' experience with the engineering, architectural and construction fields and it is principally to the men in these professions that an appeal is made. To make the story real, I have selected a few true examples purposely withholding names places, etc., as my intention is not to burn down a few houses but to ignite a larger fire, and to inspire men to a general house cleaning program. I bear malice toward no group or no individual but am tremendously concerned with the infiltration of moral laxity in the construction profession. If some of my statements or examples seem to be unjust or undeserving or a bit shocking or shaking, remember that such action might well be appropriate. Were you asleep in a burning building you would welcome such a shaking!

The Problem

Not long ago, Mr. D——, a structural engineer, and I visited a nearby state commissioner of public works. We had eyed the state's hundred million dollar highway program with a view toward designing a few bridges and overpasses.

The commissioner gave us a warm welcome. "A great deal of work will shortly be given to consultants," he said. We gave him a prospectus containing our experience and qualifications. He was unquestionably impressed by this prospectus and concluded the interview with warm assurance that we would be "kept in mind."

We followed up this interview with several subsequent calls, in all of which the commissioner was most friendly. At length we approached a state representative, Mr. S——, to see what he could do in our behalf. Although Representative S—— represented the party which was not in power at the time, we were assured that this made little difference and that he would be happy to see what he could do.

A few days later the telephone rang. The voice on the other end of the line was wary. Mr. O——, this is Mr. A——. I'm chairman of the B—— State X—— Commission and just had a nice visit with Representative S——. I believe we have some good news for you. We shall be glad to award you the job of designing one or two of the proposed bridges. You understand, of course, that it is customary to make a small contribution to the political campaign fund of the party—to be exact, 10% of the fee is usual."

My associate and I promptly turned down this proposal. Mr. A—— was nonplussed at our refusal; he was obviously accustomed to having such offers accepted without question.

A few weeks later, we learned that the job of designing twenty of these bridges and overpasses had been awarded to a firm owned in part by a close relative of a politician in high office.

* In collaboration with Walter A. Snell.

This is graft, unquestionable and undiluted. Last year, by similar means with variations, an estimated two and a half billion dollars in public funds were stolen! Even in these days of massive federal budgets, two and one-half billion dollars is a lot of money—about $15 on the average tax rate, three times the amount spent yearly on education, enough to clothe comfortably every person in the United States, enough to buy each family in the United States a 21-inch deluxe television set every three years.

Those who aren't in a position to know facts illustrated in this true story might well ask a few questions! How can corrupt politicians steal two and one-half billion dollars right out from under the public's nose? Why is the public largely ignorant of this vast graft? How can America, as leader of the world, criticize the graft and corruption of other governments and yet tolerate that at home which staggers the imagination? Why does not "somebody do something about it"? What can we do about it?

No echelon of our government is free from guilt. Municipal, state, and even federal politicians are guilty. Their system of obtaining this graft has been carefully worked out; the arrangements are strictly private and consist principally of "kick-backs and contributions" from engineers, architects, contractors and materials manufacturers engaged in the construction of public works. The system is so deeply entrenched that only rarely is the public aware of its existence and only then when some politician, fallen from grace, is made the scapegoat by his own political party and, rarer yet, when one is indicted and convicted by some "reform" district attorney. In most cases the system operates smoothly, to the extent that men are willing to pay as much as $10,000 for a political job which pays no salary. Even 90% of the men in the construction industry themselves are ignorant of exactly what goes on and how they are being taken advantage of by a compromising few.

The principals in the construction industry are well aware of the strangle-hold these ruthless politicians have on them. Yet collectively they have done little about it. The majority of these men operate their businesses on the principle "one must eat" rather than on the moral standards of good business. If they should oppose the system individually, they would commit professional suicide. And yet collectively they have failed to put a stop to these corrupt practices because of mutual distrust, fear of competition and just plain lack of backbone. This fear of "sticking one's neck out" even extends to engineers engaged by our institutions of higher learning to mould our future designers and builders!

More Examples

Let's consider a few more examples. A few years ago, I collaborated with Mr. L——, an architect, in the design of a large municipal structure for an industrial city with a population of about fifty thousand. Mr. L—— had been retained under an honest administration; he had made considerable progress on his design when a new administration took over. A new "building committee" was appointed with the mayor as chairman ex officio. Mr. L—— was approached and informed that he must make a contribution of $15,000 to be divided between the mayor, the committee and the political campaign fund. Since the architect's fee was somewhat under this sum, he was instructed to make arrangements with the contractor to obtain this money from the job. The architect refused and agreed to finish the job only if no demands what ever were made upon him. When, after much deliberation, the mayor and the committee realized the difficulty of explaining to their constituents the necessity of changing an architect of such prominence in the midst of his work, they decided on a different strategy. They dealt directly with the contractor and secured far more funds than they had originally demanded.

This is the typical approach of the corrupt politician. Yet, only rarely, as in

the case of Mr. L——, does a member of the construction industry resist such an approach. Usually, as in the case of this contractor, they acquiesce most readily to these corrupt demands with the attitude that such acquiescence is customary and necessary to secure and hold a public works job.

Twelve years ago, America was feverishly re-arming, and army camps and airfields were being built everywhere. Engineers and architects worked overtime to keep up with the military demands for more training facilities. Upon the initiation of this program, all engineers and architects of consequence in an eastern metropolitan area were invited by a Washington representative to a meeting supposedly concerned with the technical details of the program. When the meeting convened, its true purpose became all too obvious. That purpose was to explain the 5% kick-back involved in these federal defense jobs and the channels that had been established to receive them. Of the several scores of firms attending this meeting, only two demonstrated courage enough to oppose this game and refuse to "play ball." In our present re-armament program there is every evidence that the same kick-back procedure has been followed.

Not only does inertia encourage such corrupt practices, but every sizeable city has its group of favored engineers and architects, generally of questionable ability, who are so favored because of their willingness to "cooperate." These men make little pretense of being good engineers or architects. They are interested only in making money and care little how it is made. They have successfully blackened the eye of the entire construction profession.

A prime example of such men is the well known firm of M——, T—— & B—— located in a large coastal city. Less than four years ago one of their key men admitted paying twenty thousand dollars in bribery to a political boss of an industrial town in payment for being granted a job designing a municipal sewage treatment plant. Then again, about three years ago, when a group of various engineers were invited to submit proposals to a small nearby town for certain improvements in its sewage system, most of the engineers offered an approximate estimate of $200,000 as the cost of such improvements and agreed to take the job in accordance with standard ethical practices. Yet the firm of M—— T—— & B—— informed the town that, through their special abilities, they could build this system for only $150,000. With this and an appealing sales talk plus a substantial bribe for one of the committee members, the firm successfully obtained the design work. When the job was completed, the costs ran well over $300,000. The committee was certain that there was collusion between the engineering firm and the contractor, but they could prove nothing.

Not only has this firm constantly obtained its jobs by bidding under the standard published fees, but it has constantly collaborated with certain equipment and materials manufacturers and specified their products exclusively for the price of making their design for them, plus a substantial cash kick-back. In one instance in which they specified a certain product, the bid came to $10,000. However, the client, knowing something of construction prices, suspected foul play and forced the use of a material of equal quality which came to only $900; this netted a saving of $9,100.

This group of engineers has made their services so profitable to the corrupt political bosses of many cities that they are almost constantly being forced down the throats of architects as collaborators on large jobs.

F.B.I. Hands Are Tied

When they hear of these facts, the first question people ask is, "Why doesn't somebody do something about it? Why doesn't the F.B.I. do something about it? Don't they know about it?"

The answer is yes: they know about it.

They are aware of innumerable specific instances; but since these instances are usually local, they remain outside federal jurisdiction.

Mr. F——, a contractor, told me not long ago that he had lunch recently with an F.B.I. agent in a well known restaurant. At the next table were two well dressed gentlemen. When they arose and departed from the room with brief cases in hand, the agent confided in Mr. F—— that these were two of the mayor's "bag" men, that they were at that moment on their way to the office of Mr. B——, one of the city's political architects who that morning had just received a substantial check, and that they were headed to receive the kick-back money. The agent hastily added that, although he personally had intimate knowledge of the situation in this city, the F.B.I. was not authorized to investigate such matters and bring the guilty to justice.

Contractors Handle the Big Money

The big money, however, comes from the contractors. While architects and engineers are consistently asked to kick-back a percentage of their relatively small professional fees, the crooked politician, by keeping these professional men involved in illicit practices, can keep them "in line" while he is dealing with the big money which must pass through the hands of the contractor.

Usually the relationship between political boss and contractor is a friendly one; and the problem of extracting funds from the public's pocket is relatively easy. The "usual percentage" expected by the crooked politician is common knowledge, and each contractor carries this additional amount in his bid. Should some recalcitrant contractor "break faith" with his corrupt client and fail to carry such an amount and, upon award, refuse to pay this predetermined percentage, he is severely punished. The political bosses may instruct the resident engineer on his job to make unwarranted demands on him and require him to rebuild portions of his work which were already correctly built. Regular payments may be delayed or withheld and false claims made concerning the "unsatisfactory" quality of his work. Many would-be honest contractors have been "crucified" by these crooked politicians.

Frequently, contractors are encouraged to choose among themselves the "low bidder" for each specific job. This practice of secret collusion makes it easier for the politician to sell the public on the idea of his integrity; from all appearances the low bidder always gets the job and no particular firm seems favored. Recently, a large midwestern contractor, Mr. D——, attempted to break in on this type of collusion in a southern metropolis. Mr. D—— submitted a bid on a large public housing project in this community; his bid was one million dollars below those of the local contractors who were in collusion. When the bids were opened, and the local contractors discovered their embarrassing predicament, they attempted to exclude Mr. D—— on the basis that his bid was much too low, that it would be impossible to construct this project for such a sum. Mr. D——, however, proved that he could not only do the job for his bid price but could still make a substantial profit. In this case, he was awarded the job. But how many millions of dollars had these same contractors and their political bosses stolen before? How long had this collusion been going on? Only they know.

Two years ago last summer another contractor, Mr. C——, told me that he was being paid $35,000 a year for disposing of the refuse from a nearby city with a population of 150,000 and that he annually received a similar amount from the revenue obtained from private dumping. In substance he said, "I don't know what I would do if the district attorney inspected my confidential books. They show kick-backs of about $25,000 per year, and they show to whom the payments were made. It would get a lot of people in trouble, including myself."

And thus these practices go on, unnoticed in most cases by the public. Although most States have passed laws requiring sealed bids by three or more contractors for all public works and although the approach of the crooked politician to the contractor is rendered somewhat more difficult, friendship and collusion between these two is still possible. And the result is a whopping theft of an estimated two and one-half billion dollars per year from the public pocket.

The People's Choice

The public has heard a great deal about corruption in high places. Crime investigation commissions have brought light in many dark and dirty corners. Mink coats, tax scandals, influence peddling, rackets in veterans' benefits, communist infiltration, post office scandals, "fixing" in the law enforcement, and RFC loans are only a few. Indignant, impatient voters came out from behind the clouds of confusion and indifference to cast their ballot for a "house cleaning." The job is too big for one man or one party. The vote was not so much for a new party but for a new moral fiber in Government!

We in the construction industry must heed this vote. If our leaders are not heedful, we must raise up new leadership. At this time the officers of our professional societies might well be selected on the basis of their ability to give courageous leadership rather than for political expediency or past technical accomplishments. Those officers of our societies who have wormed their way into the inner circle and up the ladder of secretary, treasurer, vice president and president and lack the intestinal fortitude to take a firm stand on a moral issue do not command their profession's respect. A good captain does not let his men stand around painting the cabins while the ship is sinking!

Graft Causes Even Greater Wastes

The public must know that this 2½ billion dollar graft is only a part of the waste and inefficiencies caused by this system. Many of the programs sold to the public are undesirable, poorly planned, and some, even unusable. For example, an official report of the American Society of Civil Engineers shows that 25% of all municipal incinerators are abandoned within the first few years. These stand as mute monuments to pillaged engineering fees, fake engineering, crooked deals with incinerator firms and kick-backs to corrupt politicians. The record shows far too many cases where the structures built under this corrupt system are lacking in sufficient cement or other basic ingredients and must be repaired or entirely rebuilt after a very few years instead of lasting a lifetime.

And more important than the dollars so cleverly lifted from their pockets, the public must realize that corruption breeds corruption and that such practices can only muddle the reasoning ability of their political leaders and stamp their decisions with the dollar sign. We must realize that such corruption is not concerned with public benefit but only with personal enrichment, not with the preservation of the democratic ideal but only with the advancement of personal power. We must realize that our leadership may become so polluted that it may be impossible for it to hold the minds of men at home, as well as abroad, against the militant materialism of communism. We must realize that, muddled as we are, we can never be secure from encirclement and ideological collapse, not even from actual military defeat and conquest. We must know the facts, and we must do some serious thinking. Let us not be deluded into the thinking that the election has solved all our problems.

One need only take a look at China to be terribly frightened. The Nationalist regime was riddled with graft and despite the hundreds of millions of dollars that Uncle Sam poured into that country, only a few thousand determined men with a plan inspired in Moscow gained control of all of China's 450 millions. And now

they have invaded Indo-China and Korea and are threatening to precipitate the world into an atomic war. Graft was the principal cause of the fall of the Nationalist government, even though that government had taken many steps toward true democracy. Paradoxically, at one time the United States refused to grant further aid to the Nationalists until they had cleaned their house of graft, yet at that same time, there was more corruption in the United States than there ever was in the Chinese Nationalist regime. Let's all help our new broom sweep clean!

The experiences of the past five years have been a bitter and costly lesson to the 450 million people of China. The American people must profit by this lesson; we cannot afford to learn the hard way. Unless we learn, the world may be approaching the New Dark Ages. And the fault will be ours, not because we failed to comprehend and put into practice our vast technological knowledge but because we failed to live up to the basic moral and spiritual truths of our American heritage. Our founding fathers understood these principles and founded this great democracy firmly upon them. But today we are defying these truths and, in so doing, are adulterating true democracy and are bleeding our American way of life to death.

Although this shakedown of the 30 billion dollar construction business is only one of many areas requiring attention we must take action here, as well as elsewhere, if we are to meet this threat to our existence. What can be done?

The Construction Profession's Battle

Although the immediate power to stop this annual leakage of 2½ billion dollars into the pockets of politicians rests in the hands of the construction profession, as yet almost nothing has been done or even seemingly contemplated. First of all, our profession seems oblivious of the gravity of their actions. Secondly, we seem afraid of one another, of competition and of not being successful in our own businesses. Thirdly, we have compromised and do not know how to stop. Fourthly, we lack an effective organization and red-blooded leadership.

These are reasons why the construction profession has not cleaned house, but they are not excuses. Even a small minority of architects and engineers could put an effective plan into action, convince the majority to support actively the plan and either force the remaining few to fall in line or force them out of business. The basic principles behind such a plan might be:

1. Architects and various engineering societies agree on a modern, aggressive, high level code of ethics, which would closely define the extent they may go to secure a job—no "commissions," "finder's fees," or "kick-backs" of any kind would be tolerated.
2. Competent accountants would be employed to set up a single standard system of bookkeeping which all cooperating firms would follow.
3. Selected honest accounting firms would then be employed to audit the books of all architects and engineers in each area and report all infringements of regulations to an elected board of professional men.
4. All cases reported would be judged by this board and appropriate disciplinary action imposed. Punishment might include a heavy fine plus revoking of the professional licenses of the principals of the firm.
5. A system of double check can be called by any firm suspecting the corrections of the official audit. They can call for outside auditors to recheck the books of any firm at any time but must bear the cost of such an audit if the books are found to be correct.
6. Firms unwilling to cooperate with such a plan will first be given very unfavorable publicity and, if shown to be collaborating with political grafters, will be brought to trial by the board in the criminal courts.
7. Present grievance committees which are presently almost nonfunctional should

be given *aggressive* policy and rules with teeth.

To be effective, the contractors should follow a similar plan especially tailored to their business methods. It is further suggested that the architects' and engineers' control board include two contractors as ex officio members and that the contractors' control board include one architect and one engineer as ex officio members. This interchange would permit mutual assistance and a double check on one another if the plan is to work. Only courageous men of unquestionable moral integrity should be selected on these boards.

The Statesman's Battle

If the battle for honesty is won in the construction industry, then the source of revenue for the grafters will automatically dry up. But if this battle is lost, then drastic measures may be required by men in public life to insure reform. Such measures may involve:

1. Cooperation with the reform elements in the construction industry.
2. Exposure of the crooked deals of their fellow public officials.
3. Voluntary, perhaps compulsory, opening of every public official's personal financial books for review by a citizens' control board with the aid of an applicable system of accounting and auditing.
4. Instilling of moral and spiritual awakening in the personal lives of the men in public office.

An important battle may have been won against entrenched corruption in all levels of government last November 4th but the war against corruption never ends but merely changes from a declared war to an underground guerrilla war.

The People's Battle

We, the people, are the victims of this vicious graft. As victims we should be the most interested in the search for reform. Some steps that we may take are:

1. Arouse friends, clubs, groups or churches to the tremendous urgency of this battle for public honesty as a prerequisite for the survival of our democratic way of life.
2. Dig up facts on recent corruption and have them publicized to arouse public indignation and action.
3. Nominate, campaign for, and "vote-in" honest and competent leadership.
4. Associate with men in public life; if their views and actions are dishonest, inspire and persuade them to reform or, if unsuccessful, expose and remove them from office.
5. Become acquainted with men in the construction field, inspire them into action in accordance with the program outlined previously.
6. Lastly, we are not in this fight unless we are willing to start with ourselves. We may not have paid kick-backs to corrupt men in government but what about expense accounts, "borrowed books" or a hundred lesser things. Our conscience can be very specific. And let us not forget that honesty is an absolute moral standard.

A final word. Men who steal from the public till are likely to be brilliant, influential and crafty. When cornered, however, although some may be desperate and fight, most merely turn yellow. Nonetheless we must plan the attack well for the opposition will be strong and will strike in very subtle ways.

As our men in Korea continue unflinchingly to battle the enemies of Democracy abroad, let each of us do our utmost to defeat the more deadly enemies at home. America's greatest need is a moral and spiritual awakening starting in ourselves. Then and only then can we lead the world to sanity and peace.

Engineering History—A Pedagogist's Problem*

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Are there reasons why the history of engineering, and of engineers, should be investigated and written? We believe there are and the purpose of this paper is to present those reasons and also to point out some of the problems which would be associated with such a project.

As engineers, rather than as philosophers, we are prone to demand the demonstration of a need before we extend ourselves to attain a solution. The question before us will therefore be dealt with in the manner of the engineer.

Engineering is an effective force in the community only insofar as the men who serve the profession are competent. Obviously, then, if the present day students of engineering are deficient for lack of historical prerogatives or traditions it behooves the teachers of engineering to correct the situation. Often it has been said that a man who feels pride in his own work, and in the work of his colleagues, is one who accomplishes greater things. In simpler words, a man who is proud of his profession is generally one who will make a greater contribution to that profession because of a feeling of necessity to prove worthy of it. Pride may either be false or it may be based upon sound facts. We are prone to believe that today's engineering graduate is not equipped with a sound basis for pride in our profession.

Consider the legal profession. There are few men, to our knowledge, in that profession, who are not able to speak with pride of the great jurists of the past. It has been found expedient, in this profession, to include a good deal of history in the required curricula. Therefore, the neophyte lawyer is well acquainted with the men, and their accomplishments, who have made the great advances in his profession.

In the medical profession one finds a well recognized discipline of medical history. It is true, however, that the extent to which this discipline has become established is subject to wide variation. Some medical schools possess departments of medical history which have equal stature with those departments which are either clinical or theoretical in concept. In other instances, specific courses concerning the history of medicine are required of all students. Additionally, there exist journals which are conducted solely for the purpose of encouraging and espousing the subject of medical history. Accordingly, a relatively large percentage of medical graduates are historically conversant so far as their own profession is concerned.

Consider, however, our undergraduate engineers. What does the average student know of general history, much less the history of engineering? The answer must be that he knows extremely little. Let us inquire as to the reasons responsible for this state of affairs.

To what extent has the history of engineering been evaluated and written? To what extent have the engineers relinquished their claim rights to the physicists, chemists, and mathematicians? What have we as engineers done to alleviate the situation so as to clarify the status of many of history's outstanding intellects?

No Coherent History of Engineering

To our knowledge, no coherent history of engineers, or engineering, beginning

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with antiquity and including the 19th century exists, although some segmental histories have been written dealing with particular periods, or men. Consideration of available material would seem to indicate that the history of engineering is not a continuous one but has lapsed as civilization progressed. The latter conclusion is obviously fallacious.

Fortunately, it is not necessary to dig into the lists of the unknowns before one finds the names of men who might be considered to have been engineers or who participated in great engineering works. Actually, most of the men whom we would intuitively want to call engineers have been already claimed by other groups as members of their particular histories. Perhaps a few examples, based upon intuition rather than the "Historical Method," might serve a purpose at this point.

Archimedes, thought of by some as the greatest intellect of antiquity, is most commonly known as a philosopher and mathematicion rather than as an engineer. Yet, consider his invention of the irrigation device which we now know as "Archimedes Screw." Surely here is an example of a man providing a solution for a highly practical problem. For the military man and engineer the invention of catapults and the statement of the law of levers was a notable contribution in an engineering sense. Why then should not the engineers claim Archimedes for their own rather than leaving him solely to the mathematicians and philosophers?

Leonardo da Vinci and Michelangelo, the two great contemporaries of the latter 15th and early 16th centuries, are known to all. True, the engineering and inventive genius of da Vinci has been given wide publicity of late, but what of Michelangelo? The artists and architects would claim Michelangelo for their own perhaps without considering some of the facts in the case. Whereas the architect, in the strict sense of the word, is the one who must design a building, the engineer is the one who will ultimately determine the method of construction and supervise it. In these activities, Michelangelo was outstanding. Military fortifications were of greatest importance in that period and Michelangelo was called upon to design and to construct many such works.

Pure Mathematicians

Next consider a few men who are generally known to posterity as pure mathematicians. The question which must be answered regarding these men is whether or not the mathematical work which they produced was the off-shoot of purely philosophical contemplation or whether it stemmed from mature consideration of some practical problem. Pascal, Newton, the Bernoullis, Laplace, Monge, Fourier, Cauchy, and Poncelet, to name a few, are all men whose works may be judged by the criterion of the foregoing question. A detailed study of the biographies of these men perhaps would indicate that their greatest mathematical contributions were a result of their studies of practical engineering problems and situations: Pascal in fluid flow; Newton in mechanics; the Bernoullis in solid and fluid mechanics as well as strength of materials; Euler in analytical mechanics and hydrodynamics; and so the list goes. The studies which these men made were not to lie dormant for many years but were applied, upon the presentation of the solutions, to practical problems of bridge construction, hydraulic systems, ordnance design, road construction, and all the varied fields of engineering then known.

Among those men previously mentioned both Monge and Poncelet were military engineers interested primarily in the construction of military fortifications and weapons. Monge generally is credited with the invention of Descriptive Geometry, a method of graphical solution of certain problems whose importance to the engineer is obvious to all of you. Poncelet held the positions of Professor of Mechanics at Metz and later the Professorship of Applied Mechanics at Paris. Surely the latter named positions are ones which would very easily be recognized in our engineering colleges.

Boyle, Hooke, and Lavoisier are gen-

erally considered to be outside the field of the engineer. However, in addition to their many other achievements, these men contributed substantially, and practically, to the engineering profession. Boyle might never have been able to propound the law of gases, which is named after him, had he not first been able to design and build an improved air pump, this accomplishment to be followed by the invention of a high pressure air pump. Hooke's law is known widely, but the whole field of elasticity was this man's workshop and his contributions therein have not been of a minor nature. Lavoisier, known first and foremost as a chemist, was for a period a manufacturing or process chemist, as director of the State gunpowder works. Certainly the function which Lavoisier fulfilled would be classified as chemical engineering in our present society.

There seems to be little doubt but that the man who is hailed as the greatest of the Renaissance engineers is Galileo Galilei. Volumes have been written about Galileo and possibly they represent the majority of all that has been written, or is generally known, of the history of engineering prior to the 18th century.

At the other extreme one finds Joseph Marie Jacquard who contributed to the production technology of woven materials. This man who lived during the period of the French Revolution and the Napoleonic Wars invented a weaving machine to produce figured cloth; he also invented a machine to weave fishing nets. In retrospect, the accomplishments of Jacquard may not seem as important as some that have been mentioned, but under what circumstances is the engineering profession justified in ignoring these or any accomplishments when considered in the light of the period of their fruition? It is probably the men of Jacquard's stature who represent the continued growth of engineering even more than do those who made the great all encompassing, but infrequent, contributions.

As has previously been stated, the foregoing list is based upon an intuitive choice of men and events to illustrate a point and does not constitute coherent history. However, in order to separate historical "facts" from intuition it is necessary that the criticism and questions of the professional historian be anticipated.

Questions

The questions which would in all probability be asked by the historian are the following: 1) how does one define an engineer?; 2) how does one define an engineering work?; 3) what evidence is available to substantiate the claims made?; and 4) what further evidence may possibly be available which might appreciably alter the conclusions which have been reached? These questions lead us into a consideration of what the historian calls the "Historical Method."

As engineers we are readily able to concede that in order that a problem be discussed it must first be defined so that all can conceive of its limitations. The historian feels no differently and it is for this reason that the first two questions would be asked. Who is to answer these questions? Can the engineering profession adequately do so? If not, can an interim answer be used in order that the solution proceed? With all due respect for the many brilliant men who have attempted to formulate definitions of the "Engineer" and "Engineering," it appears that we will, however, have to accept some sort of an interim definition because of the lack of universality of acceptance of any. These definitions will necessarily be stated for all to see; they will be used as the criteria of choice of subject matter.

The latter two questions regarding evidence concern themselves with the methods of the historian in acquiring materials and establishing historical "fact" from these materials. It is not within the scope of this paper to go fully into a discussion of the "Historical Method" but merely to present its salient features. Gottschalk[1] says, "Historical Method consists of (1) the collection of probable sources of in-

[1] See Bibliography.

formation; (2) the examination of those sources for genuineness (either in whole or in part); and (3) the analysis of the sources or parts of sources proved genuine for their credible particulars." This is not a task to be taken lightly or one to be approached in any but an attitude of desiring to accumulate all possible relevant material so as to be able to draw from the sources all valid conclusions and to write a coherent history. It is absolutely essential that the historian of engineering does not fail to use properly the available material The historians of science have, at times, been accused of committing this error of misuse and improper interpretation. Undoubtedly, for proper evaluation, knowledge of engineering subject matter will be essential, but it must be accompanied by a working knowledge of the techniques of the historian for ferreting out and evaluating bits of information and evidence.

The term "coherent history" will now be defined. As used here a coherent history is not one which is merely biographical, in content, but is one which takes into account the social, economic, and political conditions and their interrelations with the development of men and ideas. Any particular history must be set into its proper framework as a single part of a complete picture. This represents a large task and a difficult one requiring not only the ability to obtain "facts" from material but also the ability to weigh all the factors involved. Of course, the job may be somewhat simplified if one were to deal with a subject such as the history of Engineering Education and to consider it from its internal aspects only. Then, conceivably, the external factors could be ignored. Needless to say, there are many such facets to the overall problem which might be attacked without broaching the larger issue.

We believe a recognizable need exists for a coherent history which can serve as a working basis for a more complete understanding and pride of, and for, the engineer and his profession. The attainment of this goal will very likely be accomplished by a relatively small group within, but the support of, the whole profession, and that group must take the full responsibility of doing an accurate and worthwhile job.

Conclusion

In closing, a final consideration: in what way will the required material be accumulated and digested, and how may it be disseminated to the students of engineering? In the first place it appears necessary that interested persons must band themselves together, in the manner of legal and medical men, into groups or societies for the promotion of engineering history. Secondly, it would behoove the individual teacher to obtain historical background material, for his courses, and to make this material an integral part of his subject matter along with the more technical parts. Possibly, individual courses on the history of engineering should be established and required in the various curricula, when adequate material becomes available. In self justification, we might add that the foregoing procedures are the ones used variously by the chemists, physicists, and mathematicians as they attempt to inculcate their students with a sense of professional pride based upon adequately documented histories.

Acknowledgments

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College Notes

The annual **Cornell Summer Laboratory Course** in Techniques and Applications of the Electron Microscope will be given this summer from June 15 to June 27, 1953, by the Laboratory of Electron Microscopy in the Department of Engineering Physics. The course under the direction of Dr. Benjamin M. Siegel will have Dr. James Hillier of the RCA Laboratories, Princeton, New Jersey, and Dr. C. E. Hall of M.I.T., Cambridge, Massachusetts, as guest lecturers this year.

The course is designed for those research workers, institutional and industrial, who have recently entered the field of electron microscopy or who are now planning to undertake research problems involving applications of this instrument. Further inquiries should be addressed to Dr. Benjamin M. Siegel, Department of Engineering Physics, Rockefeller Hall, Cornell University, Ithaca, New York.

* * *

The **California Institute of Technology** has created an Engineering Science option for candidates for the Doctor of Philosophy degree. This program of study is designed to give greater and more flexible opportunities to the student whose interests extend beyond the bounds of the current engineering fields. The boundaries between the fundamental concepts of these traditional fields are already diffuse and for many students should be ignored entirely.

The option was initiated at the beginning of the 1952–53 academic year and five candidates are now studying under the program. The first degree is expected to be conferred in 1954. This option emphasizes the engineering and scientific fundamentals rather than the applied aspects, and will be particularly helpful to students interested in careers in teaching and research. The engineering science candidate will include in his studies subjects lying outside the customary engineering program, such as classical physics and physics of solids, and new fields such as jet propulsion.

The Bases of Engineering Problem-Solving Skills*

By J. F. CALVERT, *Chairman, Dept. of Electrical Engineering;* H. P. SHELLEY, *Instructor in Psychology;* AND R. S. HARTENBERG, *Associate Professor of Engineering Mechanics, Northwestern University*

Advancing technology is characterized in part by solving engineering problems arising from new and unfamiliar situations. A few great advances have been made by those who are called geniuses; but the bulk of the advance has been made by piling minor inventions and discoveries on top of each other, the many small contributions making for a sometimes overwhelming whole, and recognized as a distinct step forward. It is in this mass area, the area in which a small contribution is made by each of the many, that we need to stimulate originativeness.

Inventions and discoveries, whether great or small, result from a carefully planned strategy and/or the ability of someone with the right equipment to capitalize and exploit a chance happening or thought. A formal educational process lays the ground-work for planned attacks and traces the patterns of the strategy of the *fait accompli.* If originality in thought, design, motivation and execution could be stimulated at the undergraduate level, then the right equipment, the right man and the right time might be brought together to bear in full on a tough problem.

Industry has long been gladly paying for "Suggestion Box" items at the shop level. Given the right situation, and a bright-eyed awareness of a shortcoming, many a man has come up with an idea, sometimes because of laziness, that meant real progress. The story of James Watt may be apocryphal, but it is said that he became tired of running around turning valves by hand and devised a system of levers and strings to do the job for him. He did much more for the old Newcomen engine—he introduced the external condenser and that was really thinking. There is, however, no good reason why the general ideas, plans and methods used by the people who have demonstrated ability along lines called original should not be studied for what can be culled from them, that they may be incorporated in an integrated way into the educational program of an engineering school. This program would stimulate the development of originativeness, creativity, ingenuity, inventiveness or whatever you want to call it. We'll call it creativity. Such a program might go a long way toward fulfilling the quest for more able men in that large area of problem-solving where engineers must deal successfully with new and unfamiliar situations.

The objectives of this and the companion paper, "Problem-Solving Skills in Engineering Drawing and Descriptive Geometry," are to make a preliminary report on an exploration into what may be done to develop latent creative ability. In making such an exploration, we have made two assumptions: first, that all degrees and levels of creative ability exist among engineering students, and second, that much can be done in terms of educational procedures to further the expres-

* Given at the Annual A.S.E.E. meeting at Dartmouth, June 1952.

sion of this ability by the student and graduate engineer. In the present paper we undertake to define the abilities and work-methods which we believe are characteristic of engineers who have been successful in original work. The companion paper reports on work in progress in the graphic and hence more tangible educational areas. The joint goal is to find educational procedures which will develop these abilities and teach these methods.

Report on Work in Progress

A large amount of work is in progress in relation to engineering education and also in relation to the broad field of creativity. In arriving at suitable descriptions of the characteristics of engineers who do creative work, we have compared our ideas with the literature of both psychology and engineering and also with the opinions of those who are successfully doing original work in engineering. We are interested primarily in engineering synthesis (design and/or invention) as contrasted with analysis or even chance discovery.

At this point we wish to call particular attention to the report presented at this Dartmouth meeting by the A.S.E.E. Committee on the Improvement of Engineering Teaching. In part, it discusses our problem in a broader setting, but of necessity in less detail and without reference to related researches.

Abilities and Work-Methods

The data to be reported in this paper are primarily a list of abilities and work-methods employed by those who are successful in solving engineering problems. The abilities or talents are specific personal characteristics of an individual; the work-methods are a logical sequence of steps or operations leading to a solution. Obviously certain steps of the work-methods imply the use of certain abilities, and they will be noted as they appear. The abilities and work-methods detailed in the following are opinions: it is believed that they are valid, and as such they will define the qualities we wish to develop through formal educational experience.

I. Specific Abilities
- A. Sensitivity to Needs and Potential Solutions.
  1. Idea Fluency— the ability to recognize problems needing solution and to produce potential solutions (a quantitative concept).
  2. Originality—the ability to produce uncommon, clever, or remote ideas which depart from the traditional (a qualitative concept).

The development of sensitivity to needs and potential solutions requires practice in constantly observing one's surroundings with an eye toward utility. One needs to raise questions such as: Why is something done as it is? How could it be done differently and better? Where else could the observed principle or technique be applied?

- B. Visualization
  1. Physical—the ability to visualize in two and three dimensions, designs, systems, and physical objects.
  2. Symbolic—the ability to visualize system parts or performance in terms of mathematical or other symbolic notation.
- C. Flexibility—the ability to change from one method of approach to a problem to another, or from one method of solution to another, i.e., the ability to change "set" or strategy.
- D*. Judgment—the ability to evaluate generalizations or consequences in physical or in symbolic representation.
- E*. Reasoning—the ability to reach acceptable conclusions on the basis of technical and scientific processes and also on the basis of realistic thinking, where economy, social consciousness, and need are considered.

* It might prove desirable to employ a combined statement for these two abilities.

F. Verbal factor—the ability to communicate ideas in a logical fashion and also, when necessary, in a persuasive manner.
G. Personal relations—a number of abilities are involved, e.g., getting along with others, having an open mind, consideration for others.

II. Work-Methods

A. Defining the Problem, or Making a Clear Statement of the Goals to be Achieved.

(The material within the quotation marks is taken more-or-less verbatim from the Report of the A.S.E.E. Committee on the Improvement of Teaching.)

"In endeavoring to make a concise statement of what appears to be a single problem, one might start by listing all factors thought to have a bearing. Through classification and consolidation, a strenuous effort should be made to express these factors in a form somewhat like the following:

1. The purpose is to produce (if a design is called for)..... or, the purpose is to determine (if an analysis is to be made).....
2. To overcome the specific inadequacy of .....
3. In such a way that ....."

B. Developing Solutions and also Selecting a Solution to be Worked on.

As indicated, these work-methods may be classified in two categories. For purposes of exposition these work-methods will be listed under the two separate headings, although in practice they are interdependent.

1. Developing Solutions
   a. Reducing the defined main goal into a series of sub-goals such that if all sub-goals are achieved, the main goal is achieved.
   b. Questioning the essential character of the sub-goals and their arrangements with a view to discarding one set of sub-goals in favor of a more advantageous set.
   c. Developing one's own symbol system to reduce a problem to its most simple elements if no commonly accepted system is available.
   d. Setting up other problems less difficult than the real one but which, by the successive introduction of more factors, yield increasingly better approximations until the last becomes an acceptable representation of the actual problem under study.
   e. Interpreting potential responses from a study of limiting or boundary conditions.
   f. Developing valid analogies which reframe a new situation in a more familiar form, and thus permit the application of theory and experience in one field to provide tentative or even final explanations in another area.
   g. Skill in "brain-picking"—a technique commonly employed by engineers administering research and development which is exceedingly efficient in obtaining pertinent information.
   h. Skill in library research.
   i. Skill in the use of time and energy so as to bring the best to bear on the toughest problems.
2. Selecting a Solution to be Worked on.
   a. Checking for matches and mismatches between the probable results and the desired results to discover vital, questionable or inconsequential differences.
   b. Skill in determining the probable satisfaction to be given the ultimate user by a given solution.
   c. Being on the lookout for by-products and their potentials.
   d. Preparing honest statements about the probable results of a proposed solution.

The specific abilities of idea fluency, originality, visualization, flexibility, judgment, reasoning, and verbal clar-

ity appear to be related to developing and selecting solutions.

C. The Negotiation of the Acceptance of the Solution.

It is usually necessary for someone to negotiate the acceptance of a problem before funds and time can be secured to work on it. Quite commonly it is necessary to keep up the interest of both those financing a problem and those carrying out the work. Finally, it is necessary to "sell" the completed work. The reactions of the client, and/or the potential consumer must be considered, and the negotiation must be so packaged that it gets across before the other fellow get tired of listening.

The specific abilities of the verbal factor and personal relations are of particular importance in this phase of problem-solving.

Survey of Research on Problem-Solving

As has been indicated earlier, the foregoing lists of abilities and work-methods were developed as a result of a series of staff conferences involving engineers and psychologists. The effort also reflects a fairly comprehensive review of the literature in the field of problem-solving as well as discussions with men in this area of endeavor. There is a close correlation between the checklist of skills proposed in this paper and with the literature in the broader field of problem-solving.

All of the specific abilities listed with the exception of Item I–G, which has to do with the problem of interpersonal relations in a team research project, can be found in one form or another in the work of Guilford on creativity (4). They were part of his original hypotheses and test battery and appear to be coming out as factors in his analysis. In addition, the work of Flanagan (3) on critical requirements for research personnel, although explicitly directed at critical requirements in terms of behavior, contains reference to many of these abilities. The behaviors listed in his checklist under "Identifying and Exploring Problems" would be included under our category, "Sensitivity to Needs and Potential Solutions."

Flexibility or the ability to change set is one of the most consistently appearing factors in studies on problem-solving. It is found in Maier's (8) early work; Luchins (6) has examined this factor quite extensively. MacLatchy's (7) study stresses invariablity of problem-solving methods in children. Shaw (9) uses it to explain the greater effectiveness of group problem-solving over individual problem-solving. The need for an ability to change set can be inferred from the critical behaviors Flanagan lists under "Anticipating Difficulties" ("Outlined alternative approach to be used if first choice failed") and under "Modifying Planned Procedures," e.g., "continued to follow old method or approach without change when evidence showed that it had failed" (ineffective behavior) and its effective counterpart, "adapting alternate procedures as soon as unforseen negative conditions or difficulties were encountered."

In addition to the more-or-less specific abilities of the problem-solver as a person, it is recognized that work-methods or ways of attacking problems are also important in problem-solving effectiveness. Although dependent upon the abilities of an individual, as listed above, they are independently related to problem-solving effectiveness, i.e., two people of equal abilities might differ in their effectiveness in solving problems because their work-methods differed in effectiveness. "Defining the Problem," as we have chosen to call it, would include the behaviors Flanagan lists under "Defining the Problem" as well as those listed under "Planning and Designing the Investigation." Bloom's and Broder's (1) "Check List on Problem- Solving," around which a program of remedial training in problem-solving was based, directs attention to understanding the problem, the setting up of criteria which a solution must meet, and the implications of the problem.

The reduction of a problem into a series of sub-goals was recognized by Bloom and Broder when they attempted to get their subjects to "break complex problems into more workable parts" and "to deal with each part separately." Under the category "Developing Systematic and Inclusive Plans" Flanagan lists "outlined a plan calling for each element of problem to be studied in sequence."

Item c under "Developing Solutions" calls for the development of one's own symbol system to reduce a problem to its most simple elements. This work-method has not been discussed in the literature. However, if it is true that reducing a problem to its simplest elements is a part of efficient problem-solving, then skill in the development of a symbol system which will permit this to be done more efficiently is a work-method that should be developed.

Item d under "Developing Solutions" calls for the gradual achievement of a problem-solution by the successive introduction of more factors to less complex problems. In Flanagan's checklist we find "Presented plans which include methods of integrating one factor or phase with others"—a form of behavior very similar to what we intend. It would seem that what we have in mind is what Duncker has termed productive problem reformulation. As he puts it. "The final form of a solution is typically attained by way of mediating phases of the process, of which each one, in retrospect, possesses the character of a solution, and, in prospect, that of a problem." The mediating phases in many cases amounts to the successive introduction of new factors into an originally simpler problem.

We have found no counterpart in psychological literature for Item e, "Interpreting potential responses from a study of limiting or boundary conditions." It is a specific technique that has applicability to many engineering problems.

Items g and h, "Brain-Picking and "Library Research," have to do with the kind of behavior Flanagan places in the category of "Collecting background information." We have distinguished between reviewing the literature and getting information directly from other people because it is thought that while the function is the same, different kinds of behavior are involved. Further, since there is a substantial time lag in the publication of research and since in the area of new problems much valuable thinking and research is never published because the solution has not yet been attained in a satisfactory form, it is important to be able to get this information.

Item II–B2a, "Skill in checking for matches and mismatches between the probable results and the desired results," refers to the selection of the solution to be recommended. It is quite likely that it will be impossible to empirically distinquish between this behavior and the judgment and reasoning abilities listed earlier. Perhaps it is at this level that the distinction between abilities and work-methods breaks down. It it likely that this is a result of the fact that the inference of abilities is based on behavior and when the behavior becomes complex, work-methods and abilities become the same. The behaviors listed by Flanagan under the category, "Interpreting research results" certainly involves the same sort of behavior with which we are concerned at this point.

Items II–B2b and d are included because the engineer's problem-solving activity does not stop with the determination of a solution. He must evaluate the solution in terms of its satisfaction to the ultimate user and he must frequently be able to present his solution in a careful scientific manner. Item II–C, "Negotiation of the Acceptance of a Solution," is included because it must be done if the engineer is to carry his problem-solving activity to a successful engineering conclusion.

Experimental research in the area of problem-solving has been primarily concerned with the determination of the factors or processes involved in problem-solving or in the development of selection and achievement tests. A few of the early

studies deal with training procedures, e.g., Maier (8), MacLatchy (7), Lapp (5). The training methods were very specific in nature involving a minimum amount of transfer. Although the results are promising, the methods are not directly suitable for use in an academic setting. Recently, Bloom and Broder (1) have published a study on remedial work in problem-solving, a study that is more directly pertinent to the task at hand. Their primary interest was in teaching students how to solve problems in a testing situation, and their remedial program was primarily individual although some work was done in groups. Again it appears that their work cannot be directly applied to the classroom in an established curriculum.

Summary

What we have tried to do is to outline the generalities invoked and used by those who are successful in solving the ever-present new engineering problems. The next step would be to have our students use these elements on problems that must be met with well-marshalled attacks involving speculation and decision, theory and method. This is not a plea for new curricula, but only a suggestion that present courses might become more meaningful by the application of new educational methods and problems which teach the basic laws of engineering and fundamental techniques and at the same time lead the student to greater ability for creative work. It is the authors' opinion that something must be done at every level within the curriculum.

The authors believe that the drawing courses furnish an excellent opportunity to demonstrate, extend and coordinate the usefulness of graphical methods as key tools needed for original work in many intricate engineering fields—kinematics, machine and system design, block diagram representation of dynamic performance, and to introduce the study of both graphical and machine computing techniques. A real and rewarding satisfaction would be gained by the establishment of a powerful current flowing beyond the first year, where drawing skill would be exploited as a tool of continued usefulness.

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Problem-Solving Skill in Engineering Drawing and Descriptive Geometry*

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Engineering is traditionally a problem-solving profession. However, the many ingenious solutions of the past constitute such a wealth of know-how they put a pressure of time on engineering education; we can easily become overly concerned with student's performance in his first job out of school at the expense of his total professional development. Normally, in engineering drawing and descriptive geometry, we emphasize industrial practices of recording size, shape, materials, surfaces, etc. But engineers use drawings and drawing skill in many ways; in fact graphic techniques and engineering problem-solving are inseparable. The question is, "How do we find time for the extras?"

Most graphic solutions of engineering can be introduced as problems in instrument work, whereas the patterns and designs used are less stimulating and take the same time. In the first weeks of engineering drawing, drawing board constructions of parallel lines, perpendicular lines, scale work, and geometric division of a segment are covered. The student can be given a simple truss and shown that by drawing a diagram of lines parallel to the loads and members of the truss with the known loads to scale, the total stress in the members of the truss can be determined with very adequate accuracy. Those who are intrigued by this can easily be led to discover the reasonable assumptions that the summations of forces horizontally and vertically must be zero for coplanar forces in equilibrium, and that a figure composed of lines parallel to the action lines of these forces drawn end on end to scale must close. It is not necessary that all the men in the class master this additional coverage; there will be increased motivation to perform the construction accurately when it leads to a result that can be compared metrically with that of the other students. This is, of course, graphic statics. But a pre-view can give the stimulation of discovery and emphasize the problem-solving power of drawings. As another example we have:

1. Draw a straight line segment AB any length.
2. Construct AC and BD perpendicular to AB and any equal lengths. Draw CD.
3. Construct the midpoint K of AC and the midpoint L of BD. Draw KL.
4. Divide AB and CD into 10 equal parts and KL into 20 equal parts.
5. Number the divisions 0 to 10 from A on AB and from C on CD.
6. Number the divisions 0 to 20 from K on KL.
7. If now you connect any number X on AB and any number Y on CD with a line, it will cross KL at Z, the sum of the numbers. This is called a nomograph for $Z = X + Y$.

How accurate is your work? Do the sums check? Can you subtract 3 from 8 on this nomongraph?

Again to intrigue the quicker men and stimulate all of them to think and try to solve an unfamiliar problem, ask them to construct a nomograph for $Z = 2X + Y$, or

* Given at the annual A.S.E.E. meeting at Dartmouth, June 1952.

$Z = 2X + 3Y$. They need no further theory; the idea above can be adapted. As a real challenge, tell them that nomographs can be used for multiplication and division. Suggest $Z = 2XY$, or $Z = X^2Y$, as tests of their ingenuity.

Emphasis on Purpose

When studying orthographic projection, make the determination of necessary views and the selection of scale the student's problem. If possible give the students models to handle, measure and sketch with dimensions. If then the object is removed and the instrument drawing must be made from the student's own sketches, he will be stimulated to anticipate the predicament of anyone reading his drawing; it also emphasizes the purpose of the drawing to record information completely. Students can be asked to exchange sketches and make instrument drawings from each others sketches.

Several magazines publish monthly compilations of new devices and gadgets. Have each student select one and represent his selection with sketches and dimensions as he considers necessary to adequately describe the new article and the human need it fills.

Remind the students that some four legged devices have four wheels, some two wheels and some no wheels. What problems or requirements are best solved by each? Compile a list of free-standing devices on which you would prefer to have 4, 2, and 0 wheels respectively.

Visualization is an ability long associated with engineering. There is good reason to believe that those who can picture a situation have an advantage in solving it. Visualization of three dimensional objects or systems is a requisite for sketching. Give the students an isometric of an object with a compass indicating north, south, east, west, up and down. Then ask them to sketch isometrics of the object turned:

a. so that the given south face is west and the top is still top.
b. so that the given top is to the west and the given south face is still south.
c. so that the given top is the bottom and the given west face is still west.
d. so that the given bottom is to the south and the given east face is the bottom.

Finally have them judge which sketch best describes the object, or suggest a position that gives a sketch that is more descriptive than any of those required. Such an exercise supports the usual coverage of visualization and free hand sketching, but also involves flexibility and judgement.

Then again, we find that visualization is not enough. Can we be sure by visualization that there is a third plane perpendicular to any two given planes? Or a line perpendicular to and intersecting each of two given lines? Can we conclusively visualize that a brace cannot make an angle of 60° with both a vertical wall and the floor? Can we visualize the correct representation of an oblique conveyor perpendicular to another oblique conveyor? Can we be sure of the existence of a right triangle ABC whose hypotenuse AB is horizontal, bearing N30°W three inches long and whose side AC is frontal and 1 inch long? Can we determine the number of possible solutions visually?

Integration of Descriptive Geometry with Other Geometry

I am sure we all find engineering students well acquainted with the relations of plane and solid geometry. Thus descriptive geometry can be a problem- solving course from start to finish leading the students to see how several previously experienced geometric ideas can be combined to solve unfamiliar problems. I strongly urge that rather than building on an artificial set of rules or principles, we build all our solutions out of geometric relations with which the student is familiar. Thus, instead of being an isolated nightmare, descriptive geometry takes its place in an integrated pattern of plane, solid, descriptive, analytic and projective geometry, to-

gether with engineering drawing, an important application of all geometry.

The students know that if two points are on a plane, the straight line connecting them is on the plane; and that if a line is parallel to one line in a plane it is parallel to the plane. With just the conclusion in descriptive geometry that parallel lines have all corresponding projections parallel, the students should enjoy solving the problem of representing a straight conveyor with required bearing and parallel to the plane of a hillside represented with three points of a survey.

When the students know how to find the true length of a line segment in space, the problem of determining the distance from a given space point A to a given space line BC can be considered a new problem within their ability to solve. Certainly the most direct procedure is to connect A to B and C forming triangle ABC. Then by finding the true length of AB, BC and CA, they can form the true size and shape triangle ABC. The altitude from A to BC is the desired distance.

To stimulate thinking, students can be required to express verbally the strategy and meaning of their solutions to descriptive geometry problems. Certainly there should be no "blank-check" solutions that somehow grind out the answer if followed by rote. Each problem can easily be a new puzzle, interesting in its challenge rather than just another required example of this method or that method. Unannounced and intermixed problems that are impossible, keep the men on their toes and really startle the "turn-the-crank" boys who find too late that a minute's thought could have saved them the long struggle with a method that somehow didn't seem to work on the problem.

Realistic vs. Abstract Problems

Although realistic problem situations are often desirable, abstract geometric problems offer more possibility for analysis and logical reasoning. The larger number of variations in abstract problems give greater experience in confronting and solving unfamiliar problems. They also are an excellent medium for examining the solution and breaking it down to an itemization of the assumptions and basic relations used. Engineering problems are not truly solved until all basic simplifications and assumptions employed in the solution are recognized and their validity accepted. Experience in breaking down a solution into parts, evaluating and criticising those parts is an essential work-method listed by Professors Calvert, Hartenberg and Shelley. Also, an abstract problem dealing with points, lines and planes has application in many problems, whereas a specific realistic problem must be generalized before it can be applied in another case.

On the other hand, we and the students enjoy realistic problems. Realism that contributes to problem-solving ability is gained by the introduction of extraneous information in the statement of the problem, the listing of conflicting or incompatable criteria for the solutions or the indication of a problem situation in which the student is to act as a consultant, i.e., he is not to solve the problem but list the advantages and disadvantages of as many alternate proposals as he can. Give a driveway problem on a wooded slope and limit it to a straight driveway for ease of snow plowing. Let there be one path for the drive where no trees would need to be removed, and state that along this path construction costs would be 15% less per foot than along any other. However, arrange it so that the student finds that this treeless path is about 15% longer than the shortest possible driveway. The students can be asked to list related criteria and compare various of their own proposals. They probably will list maintenance costs, snow removal costs, grade for slipperiness in icy weather, accessability to town, convenience, visibility and safety of turn at the highway. Essentially the problem is a traditional one of a line perpendicular to another but these other considerations add interest and contribute to problem-solving ability.

There is the usual problem of a third pipe connecting two given skew pipes using 90° tees. Theoretically it is the problem of a line perpendicular to and intersecting each of two given lines. But add the information that the given two pipes cannot be removed except at great expense and trouble and ask how the third pipe can be installed with threaded connections without removing the given two pipes. At first the students may feel that there is no problem to it, and then after considering it, they may believe it impossible. Show them a standard union (coupling) and something about how it works. Soon the students will be busy determining the order of steps, cutting, threading, tightening 90° tees, this part of the union and that, and they will solve a problem that never existed before to their realization.

All in all we can stimulate and enhance problem-solving ability by orientating our emphasis in engineering drawing and descriptive geometry for increased relation to later engineering courses and graphic procedures that are essential in all engineering work.

In the News

Compilation of the 7th edition of **"Who's Who in Engineering"** has been in course for some time and the publishers report an exceptional interest and response on the part of the profession. This is attributed by the editor, Dr. W. S. Downs, in part to the service of the volume in past editions, but largely to the supporting activity of the advisory committee of Engineers Joint Council, the Societies, and the deans of faculties of the engineering colleges in recommending their eligible associates and graduates. Government agencies likewise have been helpful in listing key men for invitations to supply data, and individuals have recommended engineers of accomplishment. Indications point toward a high percentage of qualified engineer coverage.

There is still time for supplying new data or for revising records formerly printed. An intensive campaign to relocate engineers whose former addresses are no longer serviceable is under way and any engineer previously listed who has not received a communication regarding his record is urgently requested to address the publishers, Lewis Historical Publishing Company, Inc., 265 West 14th Street, New York 11, N. Y., for such service.

Undergraduate Training in the Use of Printed Materials in Engineering and Science*

By MELVIN J. VOIGT

Assistant Librarian, University of California †

Engineers, educators and librarians are agreed that if our schools are to produce competent scientists and engineers the library must somehow become more effective in undergraduate education in those fields. Various proposals have been made but a thorough analysis leads to the conclusion that progress in this direction is dependent on utilizing the classroom and teaching procedures themselves to give the instruction and experience essential to competent use of printed materials.

Librarians and educators have often discussed the question of the library's relation to the engineering student. The common criticism always seems to have been that no matter how good the libraries were, engineering students were not using them. Sometimes the blame was put on the student, sometimes on the faculty, sometimes on the library, and occasionally on the inherent nature of the engineering curriculum. While we hardly wish to encourage it, we must admit that engineering has and can be taught without a library. How well, is, of course, another question. Graduating engineers have been known to proclaim that in their four years they never entered their institution's library. This may be quite true, and it may also be possible that these same students graduated with high honors. Until a few years ago, at least, traditional teaching methods employed in many engineering schools gave the student little need or incentive to use printed materials other than his textbook and possibly a handbook or two.

One cannot help but wonder, however, how these graduates managed without this experience when they went into professional life. How many hours or months they spent solving problems by prescribed formulas and rules when these same problems could have been answered in a few minutes by making use of someone else's experience as reported in print. How many years of training it took to make up for this deficiency in their education.

With the present emphasis on the social sciences in engineering education and a changing conception of teaching procedures, it is unlikely that a student can get very far in his educational training without using libraries and through this use, learning something of the value of printed materials and their contribution to a well-rounded education.

There is, however, a distinct possibility in some schools and in some departments in others that the engineering student may yet come out with his engineering degree but with little or no experience in using printed materials in his own subject field. Consequently, he will have little realization of the importance of this material to his every day professional problems, and no ideas of where to turn to answer the questions which arise outside the realm of the formulas and rules which he expected would be infallible.

It is the intention here to point out the importance of undergraduate training in

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the use of printed materials in the students' major subject fields and to discuss methods by which such training can be accomplished.

New Educational Procedures

Recently adopted educational procedures make the consideration of this problem imperative. Engineering education is moving away from textbook-lecture-memorization patterns to methods leading to analysis of problems and their solution on the basis of knowledge of fundamentals and their broad applications. If printed materials and their use are neglected in engineering schools practicing an educational philosophy of this type, the student may be left weaker in his potential value as an engineer than when his stock in trade was a series of set patterns and formulae. I have attempted to indicate this in the following four points which illustrate the new factors in the educational philosophy as they affect the use of the librarian's stock-in-trade, the printed page.

(1) There is less emphasis on learning and using specific formulae and methods; therefore, if the student is to work efficiently in school as well as in professional life, he must be provided with the ability to find these formulae and methods in print, as well as with the ability to develop them for himself.

(2) There is greater emphasis on acquiring the background and ability which will lead to modification of methods, formulae, materials and apparatus to fit altered situations; therefore, the student must be proficient in discovering the factors which will best yield themselves to modification and the means which have or can be employed in their modification. (This is in contrast to the older conception which depended entirely on the use of standard, or learned techniques.)

(3) There is greater emphasis on building on the experience of others; therefore, the student must become efficient in finding as well as in making use of the reports made by his predecessors in the field.

(4) It is believed that the approach used leads to greater efficiency in reaching the solutions to problems, due to clearer analysis of the factors involved; therefore, it is possible to evaluate and make greater use of the short-cuts and partial solutions provided by the experience of others in working through the increasing complexity of scientific concepts and procedures.

If these premises are correct, the library cannot be considered as something extra in engineering education, but must become an integral part of the teaching program. The adequacy of the collection and staff will be determined by the success or failure of individual courses and programs as they are carried out with the educational and library purposes unified toward a common goal.

How then can the student receive the training he needs in the four short years of undergraduate education? In the first place these objectives are not entirely new. Even when not specifically expressed they have often been carried out, at least in part, in many engineering courses.

Librarians and engineering educators will find on investigation that there is a good deal more training of this kind going on in their institutions than they realize. Such training is not being done in special classes on engineering literature or in orientation programs, but it is being done in many classrooms in many departments. And experience indicates that only in this way can it be done effectively. The librarian's part, therefore, is not necessarily an active teaching part in such a program. More important on his part is his status of coordinator and, in some cases, activator. For while such training is being carried on, it remains scattered and in most cases uncorrelated.

The librarian working with each department can help plan and carry out a program which will insure that every

student of that department becomes familiar with all of the types of printed materials which are useful in his particular field. In a four-year program he will then have covered the same ground he might have in a concentrated course. But by bringing this contact with the literature directly into the classroom, the student learns directly of its usefulness. It is not something tagged on for his "cultural development" in which he takes, at best, a half-hearted interest.

This problem of giving the engineering student the training and contact with the literature of his own field which he needs for success in and after his formal training is primarily a problem of the upperclassman. In the freshman, and probably in the sophomore year, the student is not ready for extensive contact with these materials. It would be difficult to relate them to his current studies, and he would not realize their importance.

Early Familiarity with Library Materials Important

However, it is important that the students become familiar with library materials and their use before they reach upperclass status. A knowledge of how to use card catalogs and reference tools, some understanding of bibliographic organization is necessary on a general basis prior to specialized training if the latter is to be effective. Much has been written on methods of orienting freshmen in the use of the library, and many schools have worked out effective techniques which would be unsuitable in other situations. At Carnegie this phase of the training has been correlated with the English and history basic courses early in the freshman year. These and other humanistic and social studies courses which follow bring the student to the general library week after week, so that the knowledge and experience gained in this program is constantly and increasingly useful and serves well as an introduction to the more specialized library usage of upperclass years.

Specific methods of carrying out the desired objectives relate primarily to a program of training the junior and senior engineering student in the use of printed materials in his own subject field. Obviously more can be done in some departments than in others. It takes a will to do by the department as well as the library. Success in one department, however, furnishes live ammunition to use with others less enthusiastic.

Usually the use of technical sources of information can be practiced to some degree in all departmental courses in connection with regular assignments. However, the nature of the material often dictates that certain courses carry a larger part of such practice than others. Especially useful for this purpose are the so-called seminar courses used in many departments to give students experience in verbal expression.

The librarian's only direct contact with a training program may appear at this point. At an early meeting of such a seminar the librarian can profitably use one period to introduce and give basic instruction in the sources of technical information available (handbooks, textbooks, and periodical literature). The use of the library catalog can be reviewed and bibliographic and abstracting and indexing services needed to locate information needed in making seminar reports can be introduced. Throughout the seminar it is possible to make increasing use of library resources. Such a course which has as its primary purpose the training of the student in oral communication and the orderly organization and presentation of technical matter should make constant use of both older and newer literature of a serial nature, and is ideal for training in the use of abstracts and indexes, and for experience in utilizing periodical information. Assignments can insure that the student progresses gradually from semi-popular periodicals to transactions of technical societies as sources for his seminar reports.

Many departments make use of a senior thesis or problem One of the seminar talks may be based on plans for

this thesis, following a survey of the experience of other investigators as revealed by a literature survey. This may be followed toward the end of the year by a presentation of the results of the thesis and an interpretation of it in the light of previously published data or experience.

The selection of material for the seminar talks and theses should be done in interviews with a departmental advisor who can profitably give additional practical advice on methods of finding suitable material in the library.

In departments in which seminars and senior problems are not a part of the curriculum the opening wedge may be more difficult to drive. However, it would be rare to find a department where some junior level course and its instructor would not be interested in providing the start needed. Subjects such as organic chemistry are perfectly adapted to such introductions. A recent final exam in one course began this way:

"In what book, journal or other reference source would information on each of the following subjects most probably be located? Give only one reference source for each subject; if you cite more than one source, only the first one named will be graded. Do not cite abstracting journals."

It is obvious that students in this course have had an introduction to scientific literature.

A good example of a course well-adapted to these objectives has been a senior course in metallurgy which is planned to teach the student to solve engineering problems through the application of the basic science and engineering learned in earlier courses together with engineering technology from printed sources. Teams of students divided as a "plant metallurgist," "materials engineer," "production manager," etc. present two case studies during the semester. One study is on the selection of a material and one on the selection of a process for a product. Here library materials are combined with instruction and outside aid in a combination common to industrial procedures. The library is used to learn the nature and duties of the students' particular assignment as well as the properties of the materials, features of the process, etc. pertinent to his part in the engineering analysis and decision. This information is combined with that obtained from letters or interviews with men in industry and instructors and research personnel on the institution's staff.

This course presents an opportunity to introduce the student to a wide variety of printed source materials. The instructor constantly brings out new types of materials and points out their usefulness for particular purposes. Among these are handbooks and treatises, both general and specific; trade catalogs, and data sheets; government specifications and reports; and reference works on standards and testing. Periodicals, abstracts, and indexes are used in a variety of situations leading the student to determine their varying usefulness for particular types of information. Because of their limited experience, the students must base their engineering decisions almost entirely on data and methods gleaned from printed sources and applied in situations which are new to them.

Make Course Practical

To make the course as practical as possible, real cases are used to demonstrate the printed materials most useful in particular situations. The primary sources used by a metallurgical engineer in an automotive firm, those most important to an engineer in the research and development division of a steel manufacturing company, those used by a materials engineer in an electrical products firm, and finally those most useful to a metallurgical engineer in a large government arsenal are listed, discussed, and investigated. These sources were prepared with help of engineers actually in these various positions.

In many courses it is possible to stress the importance of association with other engineers in technical societies. The tie between these personal associations and printed materials has often been over-

looked by librarians and it is certainly one which needs to be understood and practiced by the engineer and scientist.

I have described briefly a few specific courses which lend themselves most easily to the purposes of library identification with undergraduate teaching. Others must also be used to insure a complete coverage of printed sources of information. A few examples will be sufficient to show the type of problem which may be inserted at a variety of points in the curriculum.

(1) Students may be assigned problems for which complete data (e.g., physical properties) are not given, and the student must find sources for the data and convert it to proper units.

(2) Students may be required to obtain production statistics and current price comparisons for common materials—metals, chemicals, etc. from unspecified library sources.

(3) Instructors may inform students that certain recent technological developments will not be covered in lectures, but that the student must learn of these developments from current publications and will be held responsible for this information in quizzes.

(4) Principles of abstracting may be introduced by requiring students to write one-page abstracts of good, unspecified articles on particular subjects.

It is hoped that this description of a few of the many possible procedures will give some indication of how the library may identify itself with engineering education. Often it is necessary to start in one department and it may be difficult to carry such a program to another. However, if one department is found in which there is a real interest, a start can be made which will make possible gradual expansion to other departments. Experience indicates that it takes a good many years to show much real progress in some departments. A program such as this cannot be started until the curricular program is put in step with the newer concepts of engineering education, and this in turn may depend on changes in leadership within the department.

The rewards, however, are great, for a well-coordinated training plan, coupled with a good, active library collection, a well-trained staff and a well-planned library will insure that engineering education, graduate and undergraduate, has made the library an integral and essential part of the student's preparation for a useful professional life.

Communications—The Responsibility of Management and the Management Engineer*

By ALEX W. RATHE

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The Tower of Babel

In the assignment of my topic, the Chairman has bracketed together three things: Communications, Management, and the Engineer. These three form a tripod; they have done so from time immemorial.

Already in the most revered of all records in the history of mankind, the Bible, there is a well-known account of the interdependence of these three. It is the tale of one of man's first large-scale engineering projects, the construction of the Tower of Babel, whose top was meant by human foolhardiness to reach unto heaven. The undertaking was stopped cold when The Lord gave each man a different language so that project management could not stem the chaos which resulted at once from the people's inability to communicate.

Since then and through all centuries, confusion and defeat has faithfully followed whenever communication has failed between persons.

Communication in Human Life

Building the lines of communication has traditionally been an engineering task. In the broadest sense of human relations, the shape of world affairs has been changed, often in near-revolutionary fashion, whenever progress is made in communications.

World-shaking events were forecast in the developments which led from stage coaches to jet airliners, from carrier pigeons to facsimile transmission, or from the pictures which the Neanderthal Man drew on the walls of his cave to printed matter to radio to television.

On the narrow scale of management, communication has been of similar, overriding significance. This is so because management's sole "raw material" is people. Whatever management does, it accomplishes through people. And the only way to energize, motivate or activate people, to spur them on or to hold them back, is by communication.

Again, it was primarily the engineer to whom has fallen the task of providing these channels of communication. He has helped to furnish management with quite a number. Each and everyone of them shows the imprint of typical engineering thinking and approach. Together, they form the foundation, structure, and pathways within which business, commerce, government, schools, and any other human pursuits are directed by their managements. Here is a brief glimpse at the vast variety of equipment in management's arsenal of communication.

The Manager's Communication Center

The basis of all activity is provided by Company Policies. In them, the execu-

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tives lay down general principles which will, under the prevailing circumstances, best guide operations to the desired objective. Policies thus give a broad "fix" on the target, sound the keynote for everything that goes on.

To mention one example: After determining that it would be most advantageous in its particular situation for Chevrolet to market its automobiles through exclusive agents, this principle was laid down as part of its sales policies which have since governed the distribution of every car produced by this General Motors Division.

Policies—for sales or any other type of work—must be reliable, unfailing, and unambiguous communications if they are to be successful in directing many and often widely scattered persons uniformly over a period of time.

Another important contribution which the engineers have made to managerial communication is Organization. This phase of planning work designs the framework within which all operations are carried on. It determines what tasks have to be performed within the firm and distributes them over the personnel in the enterprise.

Organization weaves a pattern of relationships between departments and groups, plants and offices. It is a managerial circuit diagram. Through it, we attempt to convey to everybody one and the same impression of what his job is so as to avoid uncertainty as to just exactly who is responsible for doing what. Time and again, major difficulties in organization have been caused by the problem of expressing this functional arrangement in clear, readily understandable terms.

Procedures are a third message carrier. They give operating instructions in detail. Just as procedures govern registration and many other activities in Colleges, so do purchase, payroll, inspection, engineering change, and innumerable additional procedures serve as transmission belts in industry and commerce. They get data, information, facts, ideas, decisions, etc., from one quarter to the next.

A collection of managerial communication vehicles would further include Statistics and Reports; Interviews; all Records; Orders and Instructions; Board Resolutions and Committee Minutes; etc.; in brief, every single expression—be it oral or written—from a two word "Go Ahead!" to a 300 page manual. Whatever their specific form, purpose or appearance, managerial communications are the connecting link between executive thought and operations.

They link people, steer work, and cause every single move in the engineering drafting room as much as on the factory floor, in the sales show rooms, on warehouse platforms, in mine shafts, airport control towers, the Big Board in Wall Street, or the halls of Congress. Communications are the warp and woof of every fabric in any joint human endeavor.

They are as potent within the confines of one firm in connecting its own people with one another as they are powerful in transmitting ideas beyond the factory plot to the folks outside. A manufacturer's Instruction Manual for the use or installation of his product, or Advertising, and Public Relations are examples of the many communications with which management attempts to span a bridge to its customers, to the community in which it is located, or to the entire nation.

The Building Stone of Managerial Communication

It is merely an outward recognition of the difficulties in communicating that just about every profession has developed a terminology of its own to take care of specific expressions more adequately. The seemingly hieroglyphic characters on a physician's prescription are very plain to the initiated. The layman may be baffled by legal phraseology yet the lawyer finds it a boon to his work.

That "deferred expenses" have actually been paid ahead of time is perfectly lucid to the accountant although perhaps a

trifle confusing to the outsider. And we engineers have gone further than most other groups by inventing an entire language of our own, that of engineering drawings.

In contrast, management's youthfulness as a profession, has as yet prevented such developments. It just uses the language which is spoken around it —or at least it hopes it does.

This is why all the various types of managerial communication have a very common building stone: words, everyday words. Good communications are as reliable as dial telephones; we reach the right party, automatically, if we dial the right number. The problem is to find the right word. And that is quite a problem.

Even a very slight difference in words can cause a vast difference in their reception. We could test this rather readily if we were to call a lady a "kitten" or a "cat," a "vision" or a "sight."

But although we may choose the right words, we may use too many. That has been another frequent barrier to effective communication. The Gettysburg address took 266 words, the Ten Commandments 297; but the new ruling of O.P.S. to reduce the price of cabbage required 26,911.

Much more bothersome is the vexing dilemma if the same word conveys a different meaning to different people. "It is not necessarily true," said Mr. Justice Holmes, "that the word 'income' means the same in the Constitution and in the Income Tax Act. A word is not a crystal, transparent and unchanged; it is the skin of a living thought; it may vary greatly in color and content according to the circumstances and the time in which it is used."

It goes back to this Supreme Court decision that we have to pay income tax today. This illustrates, if I may impose upon the generosity of your imagination, the significance of the meaning of one word, in different surroundings, in terms of many hundreds of billions of dollars.

The same can be shown, though, in terms which are more suited to our professional situation: A 12″ television screen was called "giant" just fifteen months ago; it could hardly command that designation today. As you know so well here in New England, Potato Grade No. 1 is second because "U. S. Fancy" comes first; Grade No. 2 is fourth because "U. S. Commercial" stands between "one" and "two." The newspaper which carries the words "Thursday—Morning Edition" on its masthead, came out at 8:00 o'clock at night on Wednesday.

It is then not just the words which count but the meaning which they have to the people who use them. I should say more distinctively, it is the meaning which the recipient of a message reads in it that determines the effectiveness of the comunication.

The problem in communications is therefore one of selecting the right words in terms of the receiver. We must make certain that our policies, organization, procedures, orders, and what not, carry to the addressee the meaning which we intend for him to find in them.

Alliance between Technical and Living Sciences

And this task sends the engineer into realms in which he must obtain assistance from other quarters. It is still the technical man who builds management's communication network today. But when it comes to its use, the executive finds his management engineer deeply concerned with the knowledge of brother professionals.

It is primarily the task of effective communication that has brought the student, teacher, and practitioner of management to the wells of information of Psychology, Sociology, Anthropology, Semantics, Philosophy, History, or other disciplines. What has already been achieved in the particular field of communication is perhaps most significantly indicated by the magnificent writings of Dr Norbert Wiener of M.I.T. on "Cy-

bernetics," itself a composite of technical and living sciences.

Forward-looking management wants all pertinent experience applied judiciously to the solution of its problems. This poses a tremendous challenge for the Management Engineer whose ambition Dean Saville once described as "to find in the crucibles of business practice ever-growing opportunities to prove that he can make a weighty contribution toward ever-greater utilization of natural as well as of human resources."

This means that we should use our engineering know-how to the limit but that we have to alloy it with the heart and feelings whose lack Gantt deplored more than 30 years ago. In communication, as anywhere in management, it is the people that count.

That recognization has come to us in management in these crucial days—crucial for world peace but also crucial for the future of management—which are sometimes called the "Atomic Age." It is perhaps more than a coincidence that it was the thinkers, pioneers, and practitioners of the Natural Sciences who found that the earth's most powerful source of energy is released when Nature's smallest building stone, the Atom, is set free.

Equally unfathomable strength will become available when the Living and Natural Sciences team up in their service to Management. Joined together, they will unshackle, from bonds of wasteful practices, degrading indignities, and distorted communications, the resources of Life's most elemental building stone, Man.

Sections and Branches

The nineteenth annual meeting of the **Southeastern Section** of the ASEE was held at the Louisiana State University at Baton Rouge on February 26, 27 and 28th.

The first day was devoted to a meeting of the Engineering College Research Council. On the following day, the meeting was addressed by W. R. Woolrich, President of the Society. L. E. Grinter gave a progress report on the activities of the Committee on Evaluation of Engineering Education. A paper on the "Historical Background of Engineering Studies" was presented by N. W. Dougherty. Other speakers included W. J. McGlothin, who presented a paper on "The Progress and Promise of Regional Education in the South," and H. H. Armsby, who gave a report on the engineering manpower situation in the United States.

The following officers were elected for the year: Chairman, J. R. Cudworth; Vice-Chairman, H. V. Flinsch; Secretary-Treasurer, L. E. Schoonmaker.

Some Applications of General and Statistical Mathematics in Industrial Engineering*

By W. GRANT IRESON

Professor of Industrial Engineering, Stanford University

1. Purpose of Paper

The purpose or theme of this session was established by Everett Laitala in his original correspondence with the speakers on this program as being the need for critical study of the status of industrial engineering. The thinking behind this program is that industrial engineers have been relying upon qualitative analysis of problems when quantitative analysis is needed. There is also the underlying idea that greater use of mathematical techniques will elevate the status of industrial engineers within the professional family.

This paper attempts to help clarify the part that mathematics now plays and can play in the industrial engineering profession. It also attempts to establish some areas in which quantitative measures may be found and used in the problems of the profession.

Dr. John M. Clark of Columbia University, has captured the essence of these questions in two of his verses, known as "K.B.'s":

When firms grow big with many parts
They learn communication arts,
And bosses, to avoid distraction,
Have formulas to guide their action.

If business seeks its greatest gain,
Can mathematics make things plain
When peering through the misty curtain
At prospects that remain uncertain?

* Paper presented before the Industrial Engineering Division, ASEE, at Dartmouth College, June 25, 1952.

2. What is Industrial Engineering?

No definition of industrial engineering has been written that satisfies a majority of those engaged in what is loosely called industrial engineering work. It is therefore necessary to clarify the meaning of the term as it will be used in this paper. I have chosen to define industrial engineering in two ways: first, in terms of special skills and techniques, which I believe is the common meaning, and second, in terms of functions of a higher order, which is the way I think we should define the bounds of the profession.

Definition by means of special skills and techniques indicates that a person is an industrial engineer if he practices in one or more of such fields as:

1. Motion study
2. Time study
3. Production planning
4. Materials handling
5. Plant layout
6. Cost accounting and budgeting
7. Quality control
8. Estimating
9. Engineering economy
10. Job evaluation and merit rating

These are jobs which can be learned in ordinary trade schools or on the job in the industrial plant, and can be performed with some success without broad, general engineering training.

Industrial engineering as defined by functions of a higher order involve such activities as:

1. Industrial and production management;

2. Various control functions involving analytical ability;
3. Plant and production engineering, including the direction of specialized work of other branches of engineering and involving broad engineering knowledge;
4. Long-range policy planning;
5. Research and development of new techniques that can be simplified for use at the skills level.

It is obvious that such functions of the higher order require broad, yet intensive training in the whole range of basic engineering subjects, including mathematics, plus analytical training in the specialized skills of industrial enginering activity.

3. The Problems Encountered Are of Two Corresponding Levels

The problems of industrial engineering represent two very different levels of mathematical accomplishment. The mathematics employed in the quantitative solution of problems in the specialized skills and techniques seldom involve anything more complicated than arithmetic, algebra, geometry, elementary calculus and statistics. The methods of solution at this level are generally prescribed by the practices of the employer and stress the numerical solution without questioning the soundness of the method. Accomplishment of routine daily tasks is the principal objective, which allows little or no opportunity for creative effort or the development of new techniques. The emphasis is upon following procedures and understanding the relationships of the divisions of an organization.

Secondary consideration is given to the solution of problems in related fields of engineering. Since the practicing industrial engineer must work with mechanical, electrical, and chemical engineers, he should be able at least to understand the numerical solution of problems in these areas. We have recognized this need by requiring industrial engineering students to take courses in the fields of thermodynamics, machine design, electrical engineering, electronics, etc.

Some of the common problems encountered by the industrial engineer at this level may be enumerated:

1. Setting time standards from time study—involving arithmetic and, in some cases, simple algebra;
2. Calculating economic lot sizes for production—involving the first derivative of a simple equation of total unit cost;
3. Establishing natural variation limits for a quality characteristic from a controlled process—involving a simple statistical technique and ordinary arithmetic;
4. Designing machine elements, conveyors, power systems, or simple trusses—involving, at the most, integral calculus.

You can see that these problems, which are the most difficult of the common industrial engineering problems of this level of activity will not tax the mathematical knowledge of any third year university student. In most cases formulas are employed so that a person can obtain the numerical solution without even understanding why he is using that particular formula. This is one of the reasons why we, as industrial engineers, have been subjected to considerable criticism. For numerous reasons both other engineers and businessmen hold on to the idea that this is the limit of the industrial engineering profession. I propose that this is no more representative of industrial engineering than work on the detail drafting board is representative of the mechanical engineering profession. These activities merely provide the training period for young industrial engineers who should be reaching for something higher. I think that it is safe to state that one who continues at this level for a lifetime is not a professional industrial engineer but a technician.

4. The Second Level is the Goal

Industrial engineering should be measured by the second level of accomplishment. Here mathematics becomes considerably more important and presents a real challenge to any of our current engineers. Differential equations, probability theory, statistics, statistical inference and the games theory are essential to the numerical solution of these problems.

The nature of industrial engineering problems of this level is unique in several respects. The typical problem requires the choice of one of a number of alternatives under these special conditions:

a. Information is incomplete and cannot be correctly or completely ascertained in a reasonable time or at a reasonable cost;
b. Considerable risk is involved with serious consequences resulting from an improper choice;
c. More than two parties are interested in the solution;
d. The outcome of the problem is likely to be affected by strategy and bluffing;
e. The solution should be quantitative; qualitative solutions are generally not acceptable and are little better than guesses.

It seems obvious from this analysis that the nature of the problems dictates the use of probability theory and games theory as the basis for solutions, with advanced calculus, differential equations and matrix algebra being employed in the derivation and development of suitable equations.

Operations Research, or its counterpart, Industrial Research employing the same methods, will play a large part in the development of concepts of industrial engineering. Morse and Kimball have defined operations research as "a scientific method of providing executive departments with a quantitative basis for decisions regarding the operations under their control." The authors stress the fact that the operations analyst does not make the decisions; he is free of that responsibility so that he can look at the problem objectively and merely determine the prospective results of the various courses of action. We generally think of this method as being a highly mathematical one, but the truth is that some of the most spectacular results were obtained in the military application of these techniques without the use of a single equation. The operations analyst has two principal problems: first, he must determine what is the real problem for which a solution must be sought; second, he must find the pertinent data on which he can plan his attack on the problem. In military practice the analyst had one great advantage which is not usually present in industrial operations: he had no other duties and could devote as much time as necessary to thought and analysis of the problem. This is an important factor to be observed as far as possible in industrial applications.

Operations Research methods can be employed to find the problems requiring solutions and to evaluate the results of the various alternatives. Our old standby, engineering economy, can and will play an important role in this matter.

In operations research it was frequently possible to design experiments which would provide the necessary data in the shortest possible time and with the smallest possible number of experiments. In other cases, the urgency of the situation made an approximate solution based upon incomplete and inadequate data more valuable than an exact solution at some later date. In still other cases sufficient data were available at the time the problem was recognized and defined to permit a rapid solution. It seems probable that these three conditions will be encountered in industrial engineering problems. Furthermore, just as in operations research, it will occasionally occur that no controlled experiments can be run because the actions of the other person or concern may vary from time to time

without the fact or the extent of the variation being known.

War time experience indicated that almost any research scientist who had become disciplined to think clearly, analyze thoroughly, seek underlying principles and get down to the fundamentals of a question could be successful in operations research. High level members of the Operations Research teams have stated that scientific training in any of the disciplines was sufficient, and indicated that it is doubtful if persons can be trained specifically in operations research methods in colleges. This would lead us to believe that sound training in the subjects enumerated at the beginning of this section would be about the best mathematical training that we can give the prospective industrial engineers for this phase of the work.

On the other hand, it is possible to give direct training in the theory of games, which, to me, appears to be the most important mathematical tool for future industrial engineers. There are some excellent published works on both the theory of games and its application to economics and industrial situations. The nature of the higher level problems, as described earlier, is complicated by the fact that the industrial engineer is attempting to make decisions regarding events that will occur in the future, and furthermore, the results will be influenced not only by this decision but by actions of competitors, legislative bodies, unions, and even the customers of any concern. The shrewd analyst can attempt to associate the possible actions with some probability of occurrence and formulate an equation by which he can obtain the maximum gain. Each event in the development of a situation can be treated as a variable which will describe the actions of the participants. In addition, coalitions of participants involved may develop and strategy will be employed by participants or coalitions of participants to gain their point in the problem.

As an illustration of a recent occurrence that fits into this presentation we may use the steel wage dispute. I have become very interested in trying to analyze the actions and counter-actions of the participants in the steel wage dispute in terms of the games theory. There were more participants in that "game" than might at first be realized. Of course the two original participants were the steel companies and the union. Very quickly the federal government came into the game as a paricipant through the imposition of price and wage controls. When the President's Wage Stabilization Board recommended a wage settlement figure the Government actually became two participants with one branch forming a coalition with the union. The public was a somewhat silent participant all of the time, but did not actually appear in the "game" until the court proceedings started. At the time of this writing the dispute has not been settled, but it is not difficult to apply some rough probabilities to the possible events that can occur and determine the approximate course of events. Without a doubt, the industrial engineers and managers of the steel companies could have set up this problem as a theory of games problem with five participants and of the "non-zero-sum" type.[2] I feel quite sure that with the information available to the companies the "moves" could have been planned well in advance of the actual events, with the probable outcome fairly well predicted.

Some more frequent industrial problems which are subject to this type of solution are:

A. Allocation of materials, labor and productive capacity to the several products of the concern in periods of scarcity.

   Any of you who have been following the electrical appliance industry in recent months will appreciate the magnitude of this problem. The effects of economic pressures on the consuming public, the saturation of the market for some types of appliances, and the limitation on the use of material and labor have

caused many companies to search for the proper balance of radios, television sets, ranges, refrigerators, laundry equipment and home freezers, in order to maximize profits. The results obtained by each company will be affected by the actions of all of the competitors, credit restrictions, promotional programs and the availability of the various products.

Along this line, one of the amazing current conditions in America is the shortage of Cadillacs.

B. Rate of manufacture by periods or seasons relative to probable sales.

All of us understand the desirability of stabilized production and regular employment, but few companies have attempted to solve the problem except by the most simple means. I believe that operations research and games theory will provide a more realistic quantitative solution.

C. Establishing order-points, maximum inventory and purchase quantities for minimum total cost.

Our economic lot-size formulas have attempted to solve the purchase or manufacture quantities part of the problem, but the order points and maximum inventory points have largely been set by guess.

D. Planning a capital investment program for industrial expansion.

The advisability of long-term commitments of capital funds depends upon a large number of factors, many of which can only be predicted and over which the company has no control. Success or failure is likely to hinge on how these future conditions are considered in arriving at the capital expenditure budget.

E. Decisions regarding incentive wages and/or profit-sharing programs.

This is a very good problem for this method of attack since the participants in the "games" can readily be identified and the interests analyzed. This is the sort of problem in which it is possible for all participants to "win," but the company assumes most of the risks in order to obtain certain advantages over its competitors.

F. The development of new techniques which can be applied by the technicians in the plant.

The development of statistical quality control and acceptance sampling are examples of how relatively simple techniques have been developed from very advanced mathematical concepts.

These problems are being solved by methods that rely more upon guesses, hunches, and the art of management which comes from experience than by scientific methods. We should be giving more thought to ways of expressing these problems in the form of equations which will reduce the risk of improper decisions.

5. What Shall be the Objective of the Mathematical Training of Industrial Engineers?

The technical problems of the lower level are fairly well covered in our accredited curricula within the framework of currently accepted methods. Progress is being made by many men who are examining these methods critically and designing new and more acceptable procedures. However, we can anticipate rather slow adoption of improved methods for its means retraining a vast number of practicing industrial engineers, but we can contribute to the adoption of improved methods by introducing our students to these methods while they are in school.

The problems of the higher order of industrial engineering will require additional consideration. Very few of us are currently prepared to handle them and

only by becoming aware of the applications of higher mathematics to these problems and learning about them ourselves can we hope to improve the situation. In the meantime we will have to struggle along as best we can, making good use of the few consultants, mathematicians, and statisticians who are prepared to give aid in the solution of these problems. Our aim should be to develop over the next ten to fifteen years a new concept of industrial engineering and begin preparing our students to take their places in the larger field by improving the mathematical program within our curricula.

6. Conclusions

In conclusion it seems obvious that the professional status of industrial engineering demands these things: (1) We must develop the mathematical concepts of industrial engineering; (2) We must train and develop competent persons in the profession; and (3) We must admit that we have not been as objective in the past as we might have been and determine to learn to use all of the tools available to overcome the adverse and unjustified criticism that has been leveled at us.

We cannot simply say, "Yesterday we were pseudo engineers, but today we are going to use higher mathematics and be truly scientific." We are dealing in a large part with human nature and human nature cannot be reduced to a few simple formulas. We must develop our science over the years, very much as mechanics or electronics have been developed. By making use of mathematical tools to analyze industrial engineering problems we can help remove the guesswork of industrial management and really approach that aimed-for goal, scientific management. If we do make proper use of these mathematical tools I do not think we will find ourselves in the situation described by Dr. Clark in another of his "K.B.'s":

To put the calculation into "calculated risk"
Write unknown future quantities as terms in an equation
With estimated average and range of deviation;
Feed into an "electric brain" and turn the proper disc,
And if the fates are not unkind in times of strains and stresses,
You may score a trifle better than the man who simply guesses.

Reserve this date . . . .

June 22-26, 1953

ANNUAL MEETING

UNIVERSITY OF FLORIDA

GAINESVILLE, FLORIDA

Stronger Engineering Graduates*

By GILBERT E. DOAN

Research Department, Koppers Company, Inc., Pittsburgh, Pa.[1]

It is well recognized that after the four-year round of courses with specialists at college whatever life philosophy the student may have brought from his home has lost its unity. The resulting disunity of thinking leads to disunity and confusion of spirit. This confusion results in weak and uncertain graduates where strong adaptable leaders are needed. His ideals and convictions *should* be shaken basically by the specialists. But before he leaves college some aid should be given him to re-form at least a tentative life philosophy based on reason and justice. *Most men should leave our colleges with a clear and worthy view of life.*

The German professors were the world's best specialists, but they turned a deaf ear to the student's professional, civic, social, and ethical problems. As a result, these students, denied guidance by their natural leaders, followed eagerly a man who offered them definite answers and positive guidance. His name was Hitler and he led his country to ruin.

Specialization and research must remain and grow both in science and in the humanities. But we must also turn out consciously integrated graduates dedicated to a life of justice, reason, mercy and truth. This is our heritage from the English universities. This integration should be the culminating phase of a man's education. It is the creative answer to subversion of all kinds.

A Solution

The first step necessary for most students is to bring their scattered and fragmentary "courses" of study together into a focus. The student's own problems provide a suitable focus—war, communism, the welfare state, and labor With just a little encouragement he can see the need for working out a rational life view to face the world intelligently. The specialists who have taught him the individual courses pay little or no attention to this need

We have provided good intellectual fare in science and the humanities, taught by competent specialists. Then we have turned our attention to extracurricular activities including athletic and social life, hoping the boy would make his own synthesis. Thus, the final step of the *intellectual* program has been omitted. We have overlooked the influence of the Oxford tutorial in aiding young men to evolve a rational life view.

This synthesis must be encouraged in small discussion groups, or in individual tutorial hours as has been the practice at Oxford for so many years. Indoctrination, of course, must be despised as abuse of students and ultimately ineffective anyway. A friendly atmosphere must prevail. Opposing viewpoints must be represented clearly. The students must be permitted to choose the topics of discussion, and the world must be looked at through their eyes. Of course, no teacher feels that he is fully competent to meet this demand (neither are the Oxford dons) but we must satisfy this hunger in students for a rational outlook with what we have to give them and not send them away empty

* Reprinted from *Mechanical Engineering* for November 1952, pages 877 and 908, with its permission and that of the author.

[1] At the time this paper was written the author was professor of Metallurgy at Lehigh University, Bethlehem, Pa.

simply because we are not "experts" in the field.

Results of an Experiment

After conducting a discussion of this kind once a week with a group of seniors in metallurgical engineering who elected this course last year, I have read their term papers. The papers showed the following features:

1. Each student is consciously constructing his own philosophy which he knows will change as he matures.

2. The philosophies are rudimentary and even shallow in spots, but a vision has been caught of what a rational life view means.

3. Not a single man felt he had been subjected to indoctrination but rather that he had been warned against it. Considerable diversity of views prevailed on any given topic.

4. Religion enters these philosophies only as a general background and in most of the papers is not mentioned.

5. A sense of social responsibility has been accepted as justified. (This alone is an accomplishment.)

6. The eight students who elected the course are enthusiastic about it All have elected the sequel for the next semester. Several remarked that this course should be required, not only for all engineering students but for all college students.

7. Several books by broad thinkers have been read by each man from the list: Eddington's "Nature of the Physical World," Sinnott's "Cell and Psyche," Lynd's "Middletown," Lilienthal's "This I Do Believe," Montagu's "On Being Human," Polanyi's "Science, Faith, and Society"; articles such as those on labor in *Fortune Magazine* and others have been read and discussed, thus opening new doors for the student.

8. The material learned in other courses such as science, economics, government, history, politics, international relations, philosophy, and biology have been related to the outlook of an engineer as he enters his profession in society, or at least he has seen in numerous instances that these fragments of knowledge *can* be related in one man's mind and should be related in his own.

9. Specific positions (admittedly temporary) have been taken with respect to the student's problems; the welfare state, private enterprise, communism, war, career ambitions, labor, and personal responsibility.

10. Highly developed technical philosophies have not been stated by the students nor taught; but each man has caught a vision of a rational outlook to which the fragments of life and learning can be related. One student remarks that most people never seem to reach a rational philosophy in an entire lifetime, and he is glad that he has at least made a start.

11. These students have become personally acquainted with the solutions, attitudes, and interests of at least one of their teachers, and one who has taken the trouble to show them clearly the directly opposite view to his own, thus breaking down at one point at least the barrier erected by the mass-production system of education between professor and student, as well as the barrier between youth and maturity.

12. The students feel strongly that the conferences should begin earlier than the senior year.

Next semester there will be guest leaders of the discussions—eminent men in politics, science, labor, and management of industry, thus bridging the gap between campus and community, between books and life as Sir Walter Moberly does at St. Catherine's. We call them "professional-development conferences" because they bring both science and the humanities into a professional focus.

Industrial interviewers who come to hire seniors are already remarking that this group seems to show a maturity of outlook and judgment greater than usually found among seniors.

It cannot be claimed that such conferences infallibly will insure that all students will build a rational life view based

on justice and reason, but for our American educational system it at least makes that achievement possible. These conferences also stimulate self-education a much-needed step. Our present-day emphasis on specialization makes a step in this direction necessary.

Urgency of the Case

Belief in justice, reason, and truth are the only foundations for these philosophies. Once we of the western democracies suspect that justice and reason are the out-of-date ideologies of a bourgeois age, mere screens for selfish interests hiding behind them and, indeed, sources of confusion and weakness to anyone who would trust in them, democracy is through.

The communists teach that the only real forces in life are economic interests, power, and subconscious desire. Justice is nothing but the will of one section; and there can be nothing higher than the longing for materials benefits—so that to talk about higher missions is just foolishness or deceit. As Professor Polanyi [2] points out, a generation has grown up full of moral fire and yet despising reason and justice. Hatred and class war thus become the means of liberating men from the delusions of truth and compassion. The Russian youth disbelieves in public morality in the way we disbelieve in witchcraft. It is not that he has never heard of it, but that he thinks he has valid grounds to assert that such a thing cannot exist. If you tell him the contrary, he will think you peculiarly old-fashioned, or simply dishonest.

For educators the problem is simple: How can young men be aided in building a rational life view based on justice and truth? The professional-development conference is one method that works.

[2] "The Logic of Liberty" U. of Chicago Press 1951. M. Polanyi, F.R.S.

Sections and Branches

The **National Capital Area Section** held its Winter Meeting February 3, 1953 at the University of Maryland. President Woolrich introduced the members of the ASEE Executive Board which had met at the University that day. He discussed some of the problems for which the Board is striving for solutions, *e.g.*, the tendency of young engineers to join unions.

The meeting's subject was "How can employers get needed engineering work done in the face of long continuing short supply of engineers? How should engineering schools assist?" This was discussed: For government by Dr. Allen V. Astin, National Bureau of Standards; For industry by Mr. Donald S. Bridgeman, A. T. & T. Co.; For engineering education by Dean Martin A. Mason, George Washington University. Several means of attacking the problem were suggested by the speakers and in the lively discussion following: Use technicians for routine engineering work; Hire more technical institute graduates; Improve capability of technicians and engineers by in-service educational training using engineering schools to aid; Employ technicians and engineers for capability rather than education alone; Improve competency of supervisors; Improve management and administration.

Integration of Chemical Engineering Fundamentals

By J. M. SMITH

Professor of Chemical Engineering, Purdue University

Probably early in the career of every teacher of upper level courses in chemical engineering, an experience has occurred impressing him with the inability of the average student to make proper use of his earlier training. In undergraduate courses in thermodynamics, it is not unusual to find at least one student each semester that is unable to utilize enough of his training in calculus to integrate $C_p dT/T$ for entropy calculations. The usual answer given when the student is questioned about such lack of mathematical technique is "Oh we studied that in Math 4," implying that it was not quite sportsmanlike to expect him to bring to bear material from an earlier course upon current problems.

I should like to examine the thesis that the failure to integrate principles from separate courses is not entirely the fault of the student. Enginering education is continually associated with the process of analysis, particularly throughout the undergraduate curriculum. The student is taught to break down a complex problem into its component parts, the solution of each of which may be simple. This analytical approach is of great value and must be a foundation stone in the building of an engineering education. However, by implication it leaves the impression that there is not a real need to be able to integrate diverse principles and concepts in a successful attack on certain types of problems. Unfortunately, the mechanics of ending a course with a final examination and receiving a final grade may also suggest to the student that he too is finished with the subject material of the course and will have no further use for it.

A number of proposals for avoiding this pitfall in engineering education have been proposed in the past, and it is not the intent here to suggest a new or original solution. Instead the objective is a description of the measures that have been used in chemical engineering at Purdue.

Chemical engineering is a sufficiently narrow field that a thorough understanding of but a few basic principles is sufficient to make a satisfactory attack on most problems in the field. This fortunate state of affairs offers a means for integrating the various courses in the usual chemical engineering curriculum. This plan, stated simply, is to broaden the scope of the problems given in one or more of the senior courses so as to require the application of a number of the principles. In this way the student is obligated to recall and utilize previous and concurrent subject materials. Such training through work with repeated problems of this type prepares the embryo engineer admirably for his career in industry. The problems encountered there are likely to be so varied and complicated that unless he develops the habit of attacking them from the point of view of the fundamentals his chances for success are limited. If he is required to utilize this philosophy while still in the university, he is off to a head start, for it has become habitual for him to analyze a problem in terms of basic concepts.

Principles of Chemical Engineering

The five principles which the chemical engineer uses in his analysis of problems in unit operations and chemical processes have been recently well stated and discussed by Kirkbride (1). These may be expressed as 1), the conservation of mass, 2), the conservation of energy (first law of thermodynamics, 3), the laws of equilibrium (second law of thermodynamics), 4), principles of rate processes, including rate of mass transfer, energy transfer and chemical reaction, and 5), the principle of economic balance.

It is not important which courses in the chemical engineering curricula are used as the integrating ground. At Purdue unit processes and unit operations are given in the junior year so that the senior thermodynamics course is employed for this purpose. At the graduate level applied kinetics and reactor design serve as the integrating area, because they offer the oportunity of using nearly all the principles in comparatively short problems.

Applications

In order to illustrate the type of problems which have been used, two examples will be given from the undergraduate thermodynamics course. In the study of phase equilibrium it is desirable to refer to the use of phase equilibrium constants in evaluating the composition of multicomponent gas and liquid phases in equilibrium. Rather than offer examples involving dewpoint and bubble point calculations, the problem of determining the composition and extent of the gas and liquid phases in partial condensation or vaporization is presented to the class. In order to obtain a practical background the operation of a partial condenser in a distillation unit may be employed. In the solution the necessity of combining principles 1), in the form of a material balance for each component, and 3), as a phase equilibrium equation, is clearly brought out.

As a more complex case, the problem of determining the final composition, temperature, and pressure after a constant volume combustion is frequently given. The internal combustion engine can be used advantageously to give the problem practical support. Conditions are chosen such that combustion is not complete but equilibrium is reached quickly, so that the principles of chemical reaction equilibria are applicable. When the conditions for heat transfer to the cylinder jacket and the initial temperature, pressure, and fuel composition are specified the problem is fixed. The necessity of a trial and error solution quickly leads the student to the conclusion that he must combine (1), the principles of conservation of mass in order to express the stoichiometry of the reactions in terms of the minimum number of variables, (3), the principle of chemical reaction equilibrium in order to relate the equilibrium composition, and (2), an energy balance, and (4), a heat transfer expression in order to relate the temperature to the equilibrium composition. This example offers, in a short problem that can be worked out to a numerical solution in an hour or two, a means of illustrating the simultaneous application of the four technical principles in chemical engineering. The calculations are not particularly involved or tedious so that the student does not become occupied with numerical computations to the point of missing the fundamental concepts.

There are an unlimited number of examples as good or better than the two described. In a course in unit operations the design of heat exchangers for high gas flow rates can be used to show the necessity of combining a basic energy balance, which includes kinetic energy changes, as well as the usual heat transfer relationships. The subject of heat exchanger design serves admirably as a medium to bring out the application of the principle of the economic balance, along with rate and energy equations. The design of flow reactors in the general

case of non-adiabatic, non-isothermal operation provides a vehicle for illustrating all the fundamental principles. Mass balances are necessary in treating the stoichiometry of the reaction or reactions. Energy balances serve to relate the temperature to position in the reactor (and the pressure also, if the pressure drop through the reactor is significant). Equilibrium relationships will be required if the chemical reactions are reversible. Three forms of rate expressions are needed for the solution: rate of chemical reaction, rate of heat transfer radially, and rate of mass transfer radially in the reactor. Finally, the optimum design solution will depend upon the cost of raw materials, cost of equipment, and operating expense, and, therefore, requires an economic balance.

Plant Design Course as an Integrating Tool

In some respects the usual plant design course in the senior year serves to correlate the separate subjects in the chemical engineering curriculum. Perhaps the most common procedure is to assign the student section a complete design for one or two different plants. This approach can be of considerable value in accomplishing the objective proposed here, provided emphasis is given to bringing together the principles studied in separate, previous courses. For example, division of the class into small groups each of which is given one phase of the plant design would not be expected to accomplish the desired result. Despite the usefulness of the design course, it is believed that the opportunities for integrating the principles of chemical engineering that exist in the other courses should not be neglected. Thus in thermodynamics 20–30 problems may be assigned each semester. If half of these involve the simultaneous application of two or more of the basic principles, considerable progress has been made in developing in the student the habit of attacking problems from the viewpoint of the fundamentals.

Conclusion

One of the important advantages of the fundamental approach is the confidence it gives the student in his ability as an engineer. He enters upon his career in industry not with the fear of insufficient factual information to attack the new problems encountered, but with the confidence based upon successful experience in solving a wide variety of problems in the university by integrating the basic principles.

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Officers
J. GERARDI, *Chairman*
R. T. NORTHRUP
J. G. MCGUIRE
C. H. SPRINGER
R. S. PAFFENBARGER
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Reliability vs. Validity of Examinations

By IRWIN WLADAVER

Assistant Professor of Engineering Drawing, New York University

Reliability and validity are the most misunderstood—or the least understood—concepts in the construction and evaluation of objectively-scored examinations. Sometimes the terms are used interchangeably by professional writers and teachers who ought to know better. But here is one case in which precision does not permit interchangeability.

It is not necessarily true, however, that reliability and validity are mutually exclusive. In fact, proof of reliability can be used to support a claim for validity. But while reliability can be *proved,* validity cannot. This statement cannot be successfully disputed, for reliability is by definition a function of statistics whereas validity is a function of human judgment, fallible as we know it to be.

The reliability of a test is a measure of its consistency. For example, if a "reliable" test were given twice to the same students—or if a retest were made with an alternate, equivalent form of the original test—the scores would be practically identical on both occasions. But we know perfectly well that we often find it impossible or undesirable to give the same test twice to the same students (except in the cases of some unhappy individuals who must take the course twice). And so three or four fairly easy statistical techniques have been devised to give "estimates" of the reliability of test scores. Proof of reliability is considered to have been obtained if the statistical manipulation gives a sufficiently high coefficient.

But the reliability of a test does not take into consideration the content of the test; all it indicates is the degree of consistency of the scores obtained. Suppose, for example, we have a group of students who know only English (if that) and we have to test them in descriptive geometry. We give them the following five questions:

1. What is your name?
2. Come si chiama?
3. Comment vous appelez-vous?
4. Vie ruhft mahn dich?
5. Kak teebyeh zahvouch?

Practically every student can answer the first question correctly and will. Unless he guesses that we have tried the same question in Italian, French, Yiddish, and Russian, he will always answer the one question correctly and always fail on the others. The test is *perfectly* reliable, that is, consistent. But we are all willing to grant that it is not a particularly good test in descriptive geometry. To say it another way, the test is completely reliable; we can get statistical proof. But the test has no validity for descriptive geometry; our judgment tells us so.

The validity of a test is the degree of fidelity with which the test measures whatever it purports to measure. And this is a matter that is not at all completely amenable to statistical analysis.

It is true that some statistical evidence is desirable. For example, if a test has high reliability, we have some evidence in support of its possible validity. At least we can know that the test will report consistent scores. If the test is inconsistent in reporting scores, to that extent validity is impaired. But statistical analysis of a whole test and each item of the test can do no more than make some contribution to the validity of a test.

Points of View

In this brief article it is impossible to do much more than name some of the more important points of view from which validity can be investigated and claimed:

1. Statistical analysis.
2. The determination of validity through the use of certain groups, that is, through correlation with outside standards themselves known to be valid.
3. The extent to which the operations required of the student—by the test—appear to parallel the operations demanded by the course of study named in the title of the test.
4. The extent to which the subject matter content of the test is in agreement with the curriculum and good teaching practice.
5. The extent to which the test has been constructed according to sound practice.
6. The extent to which other teachers and experts agree to the soundness of the test.

Notice the part that human judgment plays throughout.

Reliability can be measured and a test can be said to be reliable to a specific degree, because the measurement has a mathematical basis. But validity of a test can never be 100 per cent established, since its basis rests on human judgment —even though it be relatively expert judgment, judgment like yours and mine.

Fifth College-Industry Conference Proceedings Available

Eleven papers from the 5th College-Industry Conference, sponsored by the Relations With Industry Division of ASEE at Northwestern University on January 31, 1953, are available in mimeographed form. These can be ordered from the Secretary, ASEE Office, Northwestern University, Evanston, Ill. The price is 50¢ per copy. Please enclose a remittance with your order.

TIMELY TIPS

Curves of Distortion

By ARTHUR M. HILL

Professor and Head of Mechanical Engineering, Tulane University

Volumes have been written on "good teaching techniques" and more will come in future years. But one academic practice which might be dusted off and re-evaluated is that of "grading on a curve."

The teacher who is a "curve enthusiast" will probably fall into one or more of these classifications: (a) teachers who feel that a grade of A in a subject indicates a "crip" course; (b) teachers who are not able to adjust quizzes to the background of class work and student ability; (c) those who insist upon forcing each year's class into a set mold, convinced that each year there must be a fixed percentage making A, B, etc., regardless of the variation in student material; and (d) those who feel themselves in a position of power due to the awe and mystery with which they surround their grading system.

Part (b), "teachers who are not able to adjust quizzes to the background of class work and student ability," might be discussed further. Upon reflection, most any instructor should realize that the average student thinks of the dividing line between passing and failing as a grade of about 70%. It is a poor personnel relations job for an instructor to pride himself on a class average of 45%, and then prop up these grades to the passing level by curves. Why not give realistic quizzes which result in realistic grades in the first place?

Industrial firms spend many thousands of dollars in carefully defining the working conditions of their new employees. Why would it not be beneficial to start the first class meeting in a course with a concise discussion of the grading system? If the average of the quizzes in the course will count for two-fifths, why not tell the student so? Definite numerical brackets as to where grades of A, B, and C fall would be helpful. If *you* were the student, wouldn't *you* like to know?

In a short time, many of these students will be on training programs in large industrial plants. In most cases their achievements and progress are carefully recorded and graded. I have never known of a supervisor of these young engineers who had to resort to a curve to evaluate their performance.

Life is sufficiently complicated for students and faculty at best. Why not simplify things and discard the curves of distortion?

February 13, 1953

A Single Tube Square Wave Generator

By O. WILLIAM MUCKENHIRN

Associate Professor of Electrical Engineering, University of Minnesota

The ever increasing applications and associated analyses of square waves in electrical engineering has made it desirable if not necessary to introduce the student to this material in the early stages of his undergraduate curriculum. In the classroom this presents no problem but in the laboratory, experimentation by a large

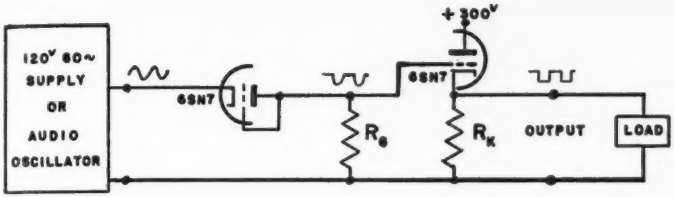

FIG. 1.

number of student groups becomes prohibitive because of the high cost of commercial pulse generators. For the study of square waves, differentiating and integrating circuits, etc., in the basic electronics course at the University of Minnesota a simple single vacuum tube square wave generator with a low internal impedance is used.

The circuit diagram of the generator is shown in Fig. 1. One of the triode sections of the 6SN7 operates as a half-wave rectifier while the other section operates as an overdriven cathode follower. In this way the cathode follower performs the function of clipping as well as preserving its inherent low internal impedance characteristic which facilitates loading. One feature of the unit is that the top and bottom portions of the square wave output are perfectly straight. This results from the fact that during the overdriven period (when the rectifier section is passing current) there is no current through R_k and therefore zero output voltage and when the rectifier section does not conduct the cathode follower operates under static conditions with a direct current through R_k which in turn provides a constant output voltage. The rise time is satisfactory for most purposes and may be adjusted by varying the amplitude of the driving unit. The magnitude of the output voltage may be adjusted by varying either R_k or the plate supply voltage of the cathode follower. Generally, an increase in output voltage is obtained at the expense of increased rise time.

As presently used, the generator is driven from a 120 volt 60 cps system through a 1:1 isolating transformer and maintains an output voltage of approximately 15 volts with $R_k = 2000$ ohms and $R_G = 10{,}000$ ohms. For other repetition rates an audio oscillator driver could be used. It is assumed that plate and filament supplies and proper driving facilities would be available where this unit would find application.

The quality of the output wave form is shown by the oscillograms of Fig. 2. The first oscillogram shows the output voltage

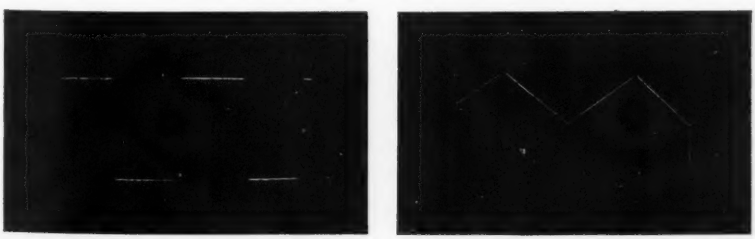

FIG. 2.

while the second shows the voltage output of a simple integrating circuit driven by the square wave generator. The integrating circuit consisted of a 50,000 ohm resistor in series with a 2-microfarad condenser. These oscillograms were photographed on a Dumont model 304H Oscilloscope. Deviations from these wave forms are likely to be observed on cathode ray oscilloscopes with limited response characteristics.

It is felt that this square wave generator which is connected by the student groups not only contributes to their understanding of vacuum tube circuits but also enhances their knowledge of non-sinusoidal circuit phenomena and should be of interest to other educators working in this field.

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Manual of Graduate Study in Engineering

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SUMMARY OF ASEE

Manual of Graduate Study in Engineering

Committee on Revision
1952

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INTRODUCTION

The original Manual of Graduate Study in Engineering was prepared by the Committee on Graduate Study of the Society for the Promotion of Engineering Education and was published in the Journal of Engineering Education in June, 1945. Instead of summarizing the background of that work we will reproduce in full the Foreword from the first edition.

By 1950, it had become clear that certain concepts of 1945 had already been changed by the impact of post-war conditions. Accordingly, in 1950, President Thorndike Saville of the American Society for Engineering Education appointed the Committee on Revision listed above. This committee found the basic concepts of the Manual to be in all respects sound and useful. Certain practices were found to have changed; for example, the gradual acceptance since 1945 of the belief that one foreign language used purposefully in the doctoral program could be more helpful than a limited ability to translate two foreign languages. Also, much experience has been gained since 1945 in the association of graduate students with sponsored research, with cooperative educational programs and with evening and extension courses. Contacts have also been extended with the problems of foreign students. To account for these changes it was found necessary to revise about one-third of the Manual but in no instance did the committee on revision find it necessary or desirable to change major conclusions or recommendations of the original document. It is felt therefore that the Manual on Graduate Study in Engineering has served a most useful purpose in guiding the growth of our graduate schools of engineering and that it will continue to serve such a purpose in the future.

The following is a summary of the Manual. Copies of the complete manual can be obtained by writing to the Secretary, Professor A. B. Bronwell, Northwestern University. Price 50¢ per copy.

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS REGARDING GRADUATE STUDY IN ENGINEERING

1. Objectives

If oversimplification is permitted, the objectives of graduate study can be stated as the development of men able to experiment or otherwise to collect, appraise, digest and analyze evidence, and trained to prepare a clear statement of the findings. Such studies should advance intellectual honesty, imagination and courage.

2. Organization

Graduate and undergraduate instruction benefit by close contact for they are

complementary functions that may be performed effectively by the same teacher, but they are sufficiently distinct in their objectives to be differentiated through certain phases of administration such as faculty designation, and budgetary control.

3. Transitional Studies

To encourage undergraduate students of unusual scientific abilities toward greater intellectual effort it is recommended that they be given more freedom in the choice of courses including such graduate courses as their development *fully* justifies and that arrangements for their first association with research and research professors be made as a part of their undergraduate programs.

4. Developing a Graduate Faculty

The development of a graduate faculty requires administrative encouragement of professional objectives, of research and scholarship as evidenced by a sympathetic understanding of the scholar's problems, appreciation of his accomplishments, financial support for his work and an adequate personal reward.

5. Admission Requirements

Fuller realization is needed that only students who rank in the upper quarter of the graduating class are likely to become strong candidates for an advanced degree. Devices such as trial registration, entrance examinations, preliminary examinations for the doctorate and others may be used to uphold the proper standards of the graduate school.

6. Degree Requirements

Formal requirements for advanced degrees in engineering are properly set by each institution although there is general agreement upon one academic year of residence study for the master's degree and three years for the doctorate. More detailed formal requirements will be needed to guide the average student, but it should not be forgotten that the graduate school remains the province of the superior mind.

7. Major, Minor and Research

The "major" should be devoted to one field of study and should include the thesis research, but departmental lines should not be restrictive in the selection of courses or teachers. One "minor" (for the doctorate) is recommended in a field of science or engineering clearly separated but contributing to the strength of the major study. The length of the doctorate residence makes two minors permissible.

8. The Thesis

A thesis is recommended for all advanced degrees in engineering. For the master's degree, it is considered to represent training in research or in the more scientific phases of design or development. For the doctorate, the thesis is considered as evidence that a candidate has made a contribution to science or to engineering knowledge.

9. Language Requirements

As an alternative to the usual required "reading knowledge of French and German" for the doctorate, it is recommended that evidence be accepted that the student has command of one foreign language which he has used effectively and extensively in relation to his thesis.

10. Mathematics

Graduate study in engineering emphasizes the mathematical or scientific approach to the solution of technical problems. It is accordingly recommended that the master's program should be strengthened by requiring one or more courses in mathematics beyond a first course in differential equations, and that the doctorate should commonly include a minor study in advanced mathematics.

11. Examinations

Greater emphasis should be placed upon comprehensive examinations of the combined written and oral type for both master's and doctor's degrees. These serve not only as a yardstick to measure the attainment of the student, but also as a

rather tangible expression of the objectives of graduate study and as a means of bringing them to the attention of students and faculty.

12. Undergraduate Courses

Undergraduate course work should be accepted for graduate credit only when taken in fields for which the student is not expected to have the prerequisites for full graduate study and then only when taken as an approved part of a graduate study program. Also, it is recommended that no more than twenty-five or thirty per cent of the program be permitted in undergraduate courses and then only in the first full year of graduate study.

13. Non-technical Studies

The recommendations in 12 above are also to be applied to graduate studies in economics, political science and administration which may be proper related optional studies for certain fields of engineering.

14. Evening Classes

Evening graduate study is accepted to be of the same significance as graduate study in the day. Its cooperative features for maintaining close association with industry are recognized to be of importance.

15. Cooperative Programs

Cooperative graduate study does not necessarily involve alteration between industry and education but might be based upon a leave of absence from industry with the thesis research in some way related to a company interest. Many other cooperative arrangements exist through institutional extension courses at industrial locations. Cooperative arrangements have been increasing and may be expected to become a very important factor in engineering graduate study.

16. Sponsored Research

Sponsored research of a clearly fundamental nature in residence has the same educational value as institutionally sponsored research and is the only kind of sponsored research acceptable for the doctorate thesis. The percentage of the students' time given to basic research should be determined objectively for assigning residence credit since much work on a research project is necessarily of a routine nature. For the master's degree greater freedom is suggested and some graduate credit is acceptable for industrially sponsored development work when placed under qualified educational supervision.

17. Industry Institutes

Graduate institutes serving a single industry face the problem of domination by that industry which may result in the use of vocational standards for measuring graduate-study objectives. This will be combatted most effectively when such institutes are closely associated with colleges or universities which foster other graduate study in science and engineering.

18. Foreign Students

A semester of orientation into American graduate study is recommended for the foreign student who often needs supporting work in English, in laboratory science, or in practical engineering courses. These are common deficiencies.

19. Student Guidance

The most practical advice to brilliant undergraduates is to enter the graduate school immediately after graduation before there is a loss of facility in the use of mathematics, physics, and the theoretical tools of engineering. Graduate students should be treated as adults, but they still need guidance in the importance of using the library and of setting up, stating, and solving problems.

20. Teaching Loads

It is recommended that teaching loads be based upon an analysis of total instructional hours including class hours, preparation, grading, and counseling for both graduate and undergraduate courses. Evaluation of the equivalent teaching load involved in direction of thesis research should be made.

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Section	*Location of Meeting*	*Dates*	*Chairman of Section*
Allegheny	West Virginia University	April 17–18, 1953	C. H. Cather, West Virginia University
Illinois-Indiana	Rose Polytechnic Institute	May, 16, 1953	H. A. Moench, Rose Polytechnic Institute
*Kansas-Nebraska	Kansas State College		M. H. Barnard, University of Nebraska
Michigan	Detroit Institute of Technology	May 9, 1953	C. C. Winn, Detroit Institute of Technology
Middle Atlantic	University of Delaware	May 2, 1953	C. Bonilla, Columbia University
Missouri	Washington University	April 11, 1953	G. F. Branigan, University of Arkansas
National Capital Area	Howard University	May 9, 1953	L. K. Downing, Howard University
New England	University of Vermont	Oct. 10, 1953	E. T. Donovan, University of New Hampshire
North Midwest	Marquette University	Oct. 9–10, 1953	A. B. Drought, Marquette University
Ohio	University of Cincinnati	May 2, 1953	H. K. Justice, University of Cincinnati
Pacific Northwest	Washington State College	April 24–25, 1953	J. P. Spielman, Washington State College
Pacific Southwest	San Jose State College	Dec. 29–30, 1953	C. M. Duke, University of California at Los Angeles
Rocky Mountain	University of Colorado	April 11, 1953	C. A. Hutchinson, University of Colorado
*Southeastern	North Carolina State College		D. V. Terrell, University of Kentucky
Southwestern	University of New Mexico	April 3 & 4, 1953	M. L. Ray, University of Houston
Upper New York	Rochester Institute of Technology	October, 1953	F. E. Almstead, State University of New York

Members of the Society are welcome at all Section Meetings

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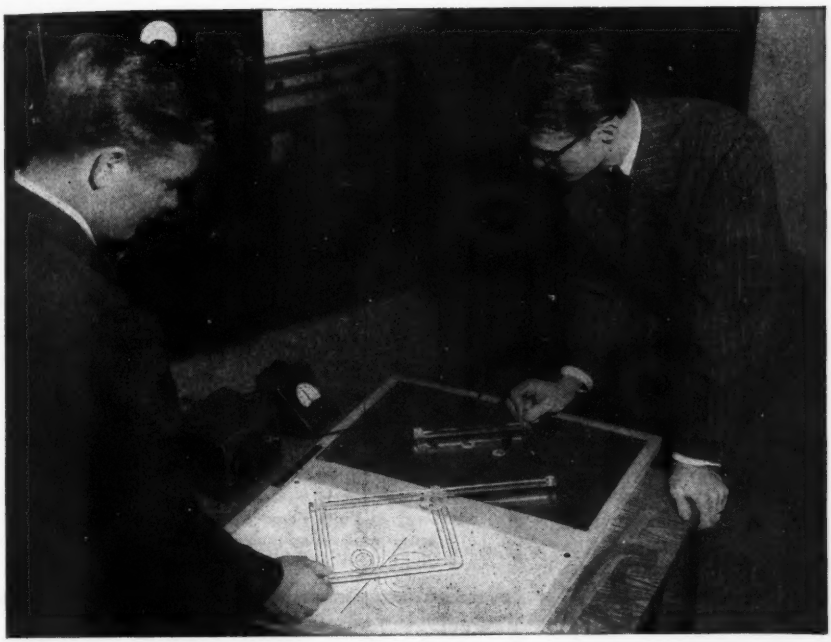

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Pipes that grew without getting bigger

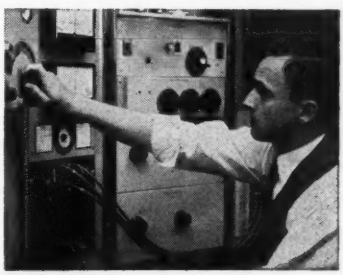
Cross-section of coaxial cable. To triple capacity, Bell Laboratories and Western Electric engineers had to make 1000 amplifiers work perfectly in tandem . . . feed repeater power along the same cable that carries messages . . . put signals on and off the line at numerous cities along the route without distortion.

Pencil-size pipes carry telephone messages and television across country through the Bell System's coaxial cable. Once, each pipe could carry 600 voices, or one television program. Now it can carry 1800 voices, or 600 voices *plus* a broadcast quality television program.

Yet the pipes aren't any larger. They are being made into triple-duty voiceways by new repeaters, new terminal equipment and other transmission advances developed by Bell Laboratories engineers.

The conversion expense is less than the cost of laying extra coaxial cables. But it calls for highly-refined manufacturing procedures, made possible only by close co-operation of Bell Laboratories and Western Electric, manufacturing unit of the Bell System.

In improving the coaxial cable system, they created more than 20 years ago, engineers at Bell Telephone Laboratories devised a new way to give America still better telephone service, while the cost stays low.



Laboratories engineer tests new triple-duty coaxial system. It marks the first time that telephone conversations and television can travel through the same pipes at the same time. With a wider frequency band being transmitted, big problem was to eliminate interference between the two types of signals.

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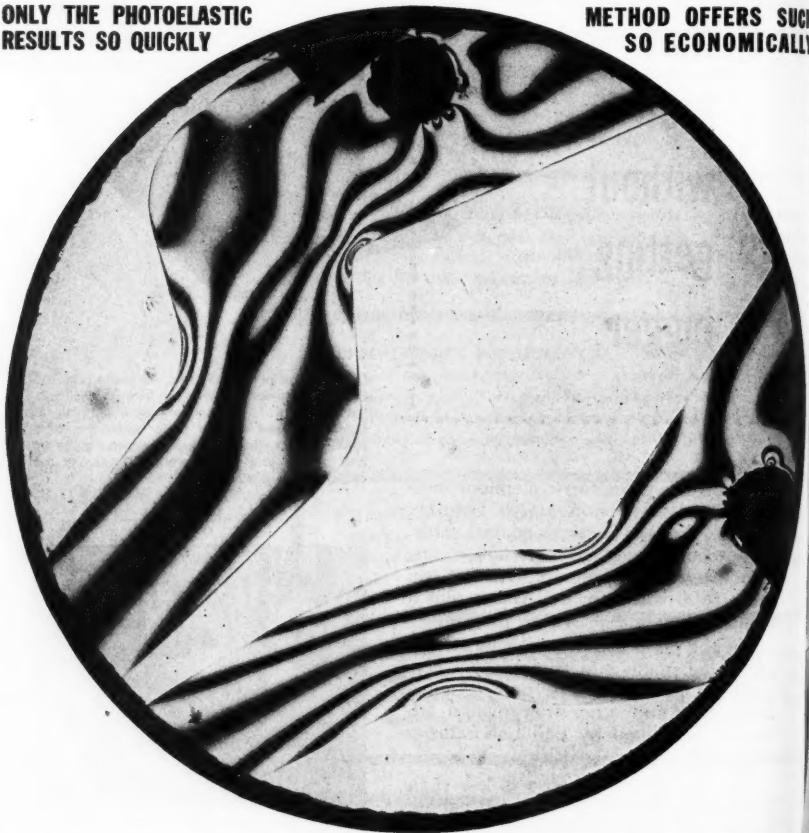

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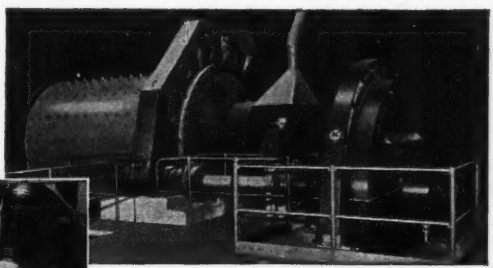
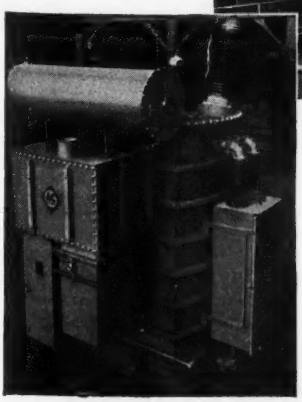
There's opportunity to try, first hand, many types of work in many industrial fields, and make a wise choice for future satisfaction and success. Trainees help choose their training locations, can change their course as they go along. Management representatives assist with guidance and advice.

The Allis-Chalmers GTC has operated since 1902. Many company executives are among its graduates, and take a keen interest in the program.

This 9½ x 15 A-C ball mill is installed in a large southwestern cement mill. A 700 hp Allis-Chalmers synchronous motor drives it.





Allis-Chalmers 25,000 kva transformer undergoing surge tests at the West Allis Works. Test floor is one of many GTC training stations.

Get complete information on the course from the nearest Allis-Chalmers District Office, or by writing to *Allis-Chalmers Mfg. Co.*, Milwaukee 1, Wisconsin.

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Honeywell fellowships help students contribute new ideas for better living

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For more information on the Honeywell Fellowship Program, write to Mr. Howard Mold, Director of Training, Minneapolis-Honeywell, Minneapolis 8, Minnesota.

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